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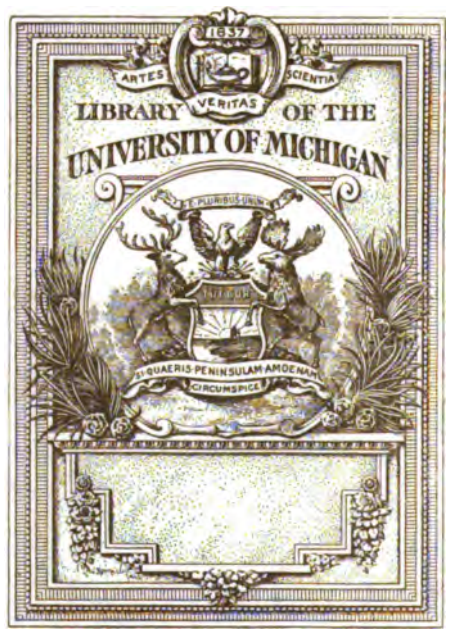
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TRANSACTIONS

OF THE

New England

Cotton Manufacturers' Association,

ORGANIZED JULY 26, 1865. INCORPORATED DEC. 1, 1894.

Office of the Association,

John Hancock Building, 178 Devonshire St., Boston, Mass.

No. 58.

National ~~association of cotton manufacturers~~

ANNUAL MEETING.

(PROVIDENCE MEETING,)

HELD AT SAVOY HALL, PROVIDENCE, R. I.

APRIL 24-25, 1895.

WALTHAM, MASS.
E. L. BARRY, PRINTER,
1895.

ENTERED ACCORDING TO ACT OF CONGRESS
IN THE YEAR 1895
BY THE NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION,
IN THE OFFICE OF THE LIBRARIAN OF CONGRESS
AT WASHINGTON.

By vote of the Board of Government, the price of the *Transactions* is $5.00 per copy for non-members, and 50 cents per copy for members for extra copies, in addition to the one to which they are entitled as a part of the privilege of membership.

CHARTER.

No. 6091.

Commonwealth of Massachusetts.

BE IT KNOWN, That whereas, EDWARD W. THOMAS, C. J. H. WOODBURY, WILLIAM J. KENT, F. M. MESSENGER, HARRY T. WHITIN, ARTHUR H. LOWE, ALBERT F. KNIGHT, ALFRED M. GOODALE, FRED C. MCDUFFIE and GEORGE W. BEAN have associated themselves with the intention of forming a corporation under the name of the NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION, for the purpose of encouraging scientific investigation and experiment as to the methods of manufacturing cotton; collecting and imparting information relating to this industry, promoting social intercourse among its members; and establishing and maintaining a library of works on textiles in the city of Boston, and have complied with the provisions of the Statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer and Directors of said corporation, duly approved by the Commissioner of Corporations, and recorded in this office.

Now, Therefore, I, WILLIAM M. OLIN, Secretary of the Commonwealth of Massachusetts, do hereby certify that said EDWARD W. THOMAS, C. J. H. WOODBURY, WILLIAM J. KENT, F. M. MESSENGER, HARRY T. WHITIN, ARTHUR H. LOWE, ALBERT F. KNIGHT, ALFRED M. GOODALE, FRED C. MCDUFFIE and GEORGE W. BEAN, their associates and successors, are legally organized and established as and are hereby made an existing corporation under the name of the

NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION,

with the powers, rights and privileges, and subject to the limitations, duties and restrictions which by law appertain thereto.

Seal of the Commonwealth of Massachusetts.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed this first day of December, in the year of our Lord one thousand eight hundred and ninety-four.

WILLIAM M. OLIN,
Secretary of the Commonwealth.

Rec'd Mass. 12-18-29 A.V.M.

137058

NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION.

ORGANIZED JULY 26, 1865.
INCORPORATED DECEMBER 1, 1894.

CONSTITUTION AND BY-LAWS.

ACTIVE MEMBERS.

ARTICLE 1. Any person who is actively engaged as President, Treasurer, Agent, Superintendent or Manager in the manufacture, printing or finishing of cottons shall be eligible for active membership.

ELECTION OF MEMBERS.

ARTICLE 2. All nominations for membership shall be made in writing, at least one week before the date of any regular meeting, and shall be considered by the Board of Government, and reported to the meeting, favorably or adversely, for the action of the Association. *Provided*, that in case the Board shall decide to report adversely upon any nomination, the member who shall have made it shall be informed of the intention so to report, in order that he may have an opportunity to withdraw the name. Upon such report active members may be admitted, if they obtain a majority of votes of the members present and voting therefor, by acceptance in writing, and paying an admission fee of ten dollars, and maintaining their membership by the payment of an annual assessment not exceeding ten dollars. Any member failing to pay two successive assessments shall cease to be a member at the end of six months from the date when such second assessment shall become due. Any member may withdraw from the Association upon payment of all arrearages, first giving notice of his intention so to do, in writing, to the Secretary, and the Board of Government may accept such resignation; and any member may be expelled for cause,

at any regular meeting, two-thirds of the members present voting therefor.

ASSOCIATE MEMBERS.

ARTICLE 3. Persons engaged in the manufacture of cotton or cotton fabrics, or the manufacture of textile machinery, or industries kindred to the cotton manufacture, may become associate members of the Association. The methods of application, nomination, election and withdrawal from the Association being under the same conditions as those provided for active members in Article 2, excepting that this class of membership does not carry with it the privilege of voting or speaking, except by permission from the Board of Government or a vote of the Association to allow permission.

The initiation fee for associate members shall be twenty-five dollars, and the annual assessment shall be double the sum annually voted for active members.

Associate members may be expelled by a majority vote of the Board of Government.

HONORARY MEMBERS.

ARTICLE 4. Honorary members may be elected, when recommended by the Board of Government, at any regular meeting of the Association, who shall be enrolled as such, and shall be entitled to attend the meetings of the Association and participate in its proceedings, without the right to vote. They shall not be subject to payment of admission fees or assessments. No person actively engaged in cotton manufacture shall be eligible to honorary membership.

ARTICLE 5. It shall be the duty of all members of the Association to make returns to the Secretary of such statistics as may be called for by him, under the direction of any committee duly appointed for the collection of statistics, when not incompatible with private interests.

OFFICERS.

ARTICLE 6. The officers of this Association shall be a President, two Vice-Presidents, six Directors, a Treasurer, Secretary, and Auditor of Accounts.

ELECTION OF OFFICERS.

ARTICLE 7. At each annual meeting there shall be chosen by ballot a President, two Vice-Presidents and two Directors; the President and Vice-Presidents to serve one year, and the two Directors shall be chosen for terms of three years.

DUTIES OF OFFICERS.

ARTICLE 8. The President, or in his absence the senior Vice-President present, shall preside at all meetings of the Association and of the Board of Government. All officers shall hold their respective offices until their successors shall be chosen and accept their positions.

ARTICLE 9. The President, Vice-Presidents and Directors shall constitute a Board of Government, and have under their care and direction all matters pertaining to the management of the Association; and five of their number shall constitute a quorum for the transaction of business. Meetings of the board may be called by the President, at such time and place as he may deem expedient, giving each member a written or printed notice of the same at least five days before the day of meeting. At their first meeting the board shall elect a Treasurer, Secretary, and Auditor of Accounts for the year ensuing, and fix the amount of compensation of the Secretary. All vacancies in their board occasioned by death or resignation shall be filled by the board; and the persons so elected shall hold their offices until the next annual meeting. The board may, from time to time, as they shall deem expedient, appoint committees, from among their own board or from the members at large, to collect statistical information, examine new inventions or processes in manufacturing goods, as also to prepare essays on subjects of interest to the Association.

ARTICLE 10. The Treasurer shall keep a book in which all receipts and payments of money shall be entered, collect all moneys due the Association, and disburse the same upon the written order of the Board of Government. At the annual meeting in each year he shall make an exhibit of his accounts, or oftener if the Board of Government require it. He shall notify the members of assessments voted, and cause them to be collected in a reasonable time.

ARTICLE 11. The Secretary shall attend all meetings of the Association and of the Board of Government, and keep accurate records of their doings. In the absence of the Secretary at any meeting, a Secre-

tary *pro tem.* may be appointed by the presiding officer, who shall be sworn to do all things, while in office, required of the Secretary.

ARTICLE 12. The Auditor shall examine the accounts of the Treasurer annually, and report at each meeting the state of the finances.

MEETINGS.

ARTICLE 13. The annual meeting of the members of the Association shall be held on the last Wednesday of April, or at such other time, and at such hour and place as the Board of Government may appoint. There shall also be a semi-annual meeting of the Association on the last Wednesday of October, in each and every year, or at such other time, and at such place and hour as the Board of Government may appoint.

Special meetings may be called by the Board of Government whenever they deem it expedient, or upon the written application of any ten members, made to the Secretary.

ARTICLE 14. All meetings of the members of the Association shall be in pursuance of a written or printed notice, addressed to each member, with the name of the President or Secretary attached thereto, and deposited in the Post Office ten days at least before the day of meeting, specifying the time and place of meeting; and at all such meetings fifteen members shall constitute a quorum for the transaction of business.

ARTICLE 15. Amendments to the By-Laws may be made at any stated meeting of the Association by a two-thirds vote; *provided*, notice of such proposed amendment be given in writing at a previous meeting, and also notice be given to each member by the Secretary, of the pendency of such amendment, ten days at least before any such meeting.

BOARD OF GOVERNMENT.

1895.

PRESIDENT.

ALFRED M. GOODALE, 50 STATE STREET, BOSTON, MASS.

VICE-PRESIDENTS.

WILLIAM J. KENT, ...	NEW BEDFORD, MASS.
FRED. C. McDUFFIE, ...	BOSTON, MASS.

DIRECTORS.

ALBERT F. KNIGHT, ...	MANCHESTER, N. H.
HENRY T. WHITIN, ...	NORTHBRIDGE, MASS.
ARTHUR H. LOWE, ...	FITCHBURG, MASS.
HERBERT L. PRATT, ...	LEWISTON, ME.
STEPHEN A. KNIGHT, ...	PROVIDENCE, R. I.
JOHN ECCLES, ...	TAFTVILLE, CONN.

AUDITOR.

J. H. SAWYER, ... BOSTON, MASS.

SECRETARY.

C. J. H. WOODBURY, P. O. BOX 3672, BOSTON, MASS.

OFFICE OF THE ASSOCIATION:

Room 501, John Hancock Building, 178 Devonshire St., Boston, Mass.

OFFICERS OF THE ASSOCIATION.

FROM THE FIRST ORGANIZATION.

PRESIDENTS.

Ezekiel A. Straw,	1865–78	Henry F. Lippitt,	1888–89
Amos D. Lockwood,	1878–80	Walter E. Parker,	1889–92
John Kilburn,	1880–83	Robert McArthur,	1892–94
William C. Lovering,	1883–85	Edw. W. Thomas,	1894–95
Richard Garsed,	1885–86	A. M. GOODALE,	1895.
J. S. Ludlam,	1886–88		

VICE-PRESIDENTS.

Amos D. Lockwood,	1865–77	Walter E. Parker,	1885–89
William A. Burke,	1865–73	Richard B. Borden,	1886–88
John C. Palfrey,	1873–76	Arnold B. Sanford,	1888–91
Edward Atkinson,	1876–78	Robert McArthur,	1889–92
A. G. Cumnock,	1877–80	Simeon B. Chase,	1891–93
Charles Nourse,	1878–81	E. W. Thomas,	1892–94
William F. Goulding,	1880–83	A. M. Goodale,	1893-95
Richard Garsed,	1881–85	WILLIAM J. KENT,	1894
J. S. Ludlam,	1883–86	FRED. C. McDUFFIE,	1895

DIRECTORS.

J. S. Davis,	1865–69	F. E. Clarke,	1869–75
Charles Nourse,	1865–78	John Kilburn,	1870-80
Phineas Adams,	1865–74	William P. Haines,	1874–78
William P. Haines,	1865–69	Cyrus I. Barker,	1875–80
Thomas J. Borden,	1865–78	Hervey Kent,	1877–81
Daniel D. Crombie,	1865–68	David J. Johnston,	1878–82
A. M. Wade,	1868–69	Walter Paine, 3d,	1878–80
D. J. Johnston,	1869–70	Chas. L. Lovering,	1878–83
A. G. Cumnock,	1869–77	Richard Garsed,	1880–81

DIRECTORS.—Concluded.

William H. Jennings,	1880–83	E. W. Thomas, . .	1888–92
Chas. D. McDuffie, .	1881–83	William H. Whitin, .	1888–93
Walter E. Parker, .	1881–85	Robert R. Smith, .	1889–92
John W. Danielson, .	1881–85	Alfred M. Goodale, .	1890–93
William E. Barrows, .	1882–83	William J. Kent, .	1891–94
Rufus A. Maxfield, .	1883–86	Herman F. Straw, .	1891–93
George W. Weeks, .	1883–86	Fred C. McDuffie, .	1892–95
Henry S. Howe, .	1883–87	George W. Bean, .	1892–95
Richard B. Borden, .	1883–86	F. M. Messenger, .	1893–95
O. S. Brown, . .	1885–91	ALBERT F. KNIGHT,	1893
Henry F. Lippitt, .	1885–88	HENRY T. WHITIN,	1894
Wilbur A. Stiles, .	1886–88	ARTHUR H. LOWE,	1894
Stephen N. Bourne, .	1886–91	JOHN ECCLES, .	1895
Robert McArthur, .	1886–89	H. L. PRATT, . .	1895
S. S. Spencer, . .	1887–90	STEPHEN A. KNIGHT,	1895

AUDITORS.

Benjamin Saunders, .	1865–71	Henry D. Sullivan, .	1873–82
John C. Palfrey, .	1871–73	JACOB H. SAWYER,	1882

SECRETARY AND TREASURER.

Ambrose Eastman, .	1865–94	C. J. H. WOODBURY,	1894

MEMBERS OF THE ASSOCIATION.

1895.

Members of the Association are respectfully requested to scrutinize the following list, and advise the Secretary, P. O. Box 3672, Boston, Mass., of change in address, of any error in regard to their names; also to inform him of the decease of fellow members residing in their vicinity.

The earliest published list of membership in the Association is dated 1866, and the names in the present list of membership which occur in this first list are recorded as dating from the first meeting, July 26, 1865.

HONORARY MEMBERS.

GEORGE ARMS		New York City.	Oct. 16, 1872.
AMBROSE EASTMAN	53 State St.	Boston, Mass.	Sept. 27, 1894.

ACTIVE MEMBERS.

Stephen I. Abbott.	Lockwood Co.	Waterville, Me.	Apr. 21, 1869.
Alfred E. Adams.	Whitinsville Cotton Mills.	Whitinsville, Mass.	Apr. 27, 1887.
Stephen L. Adams.	Stafford Mfg. Co	Central Falls, R. I.	Apr. 24, 1895.
Joseph D. Aiken	Ponemah Mills	Taftville, Conn.	Oct. 28, 1891.
F. S. Akin	Cornell Mills	Fall River, Mass	Sept. 27, 1894.
Charles T. Aldrich.	Aldrich Mfg. Co.	Providence, R. I	Apr. 28, 1886.
George E. Ames	Lawrence Mfg. Co.	Lowell, Mass.	Apr. 24, 1895.
William Ames.	Fletcher Manufg Co.	Providence, R. I.	Apr. 30, 1879.
Charles B. Amory	Hamilton Manufg. Co.	Boston, Mass.	Apr. 25, 1894.
Abel T. Atherton	A. T. Atherton Machine Co.	Pawtucket, R. I.	Oct. 16, 1872.
Edward Atkinson	Boston Mfrs. Mu. Fire Ins. Co.	Boston, Mass.	Apr. 19, 1871.
Edward W. Atkinson	Stoddard, Haserick Richards & Co.	Boston, Mass.	Oct. 27, 1886.
H. C. Atwood	Williamsville Manufg. Co.	Killingly, Conn.	Apr. 29, 1885.
James A. Atwood	Wauregan Manufg. Co.	Wauregan, Conn.	Oct. 28, 1891.
W. E. Atwood	Williamsville Manufg. Co.	Killingly, Conn.	Sept. 27, 1894.
Geo. A. Ayer	City Manufg. Corp.	New Bedford, Mass.	Apr. 24, 1895.

Charles L. Bailey. . .	Boston Manufg. Co.	Waltham, Mass. . . .	Sept. 27, 1894.
Henry A. Bailey	Chicopee Manufg. Co	Chicopee Falls, Mass .	Oct. 25, 1893.
Edwin H. Baker.	Bliss, Fabyan & Co.	New York.	Apr. 24, 1878.
Edward R. Ballou	. . . . .	New Bedford, Mass. .	Apr. 25, 1894.
William P. Bancroft . .	V.-P. James Bancroft & Sons Co.	Wilmington, Del . . .	Oct. 31, 1883.
A. D. Barker	Avon Manufg. Co.	Lewiston, Me.	Apr. 19, 1871.
W. A. Barrell.	Lawrence Duck Co.	Lawrence, Mass. . . .	Apr. 30, 1884.
Edwin N. Bartlett . . .	Sigourney Mill	North Oxford, Mass. .	Apr. 29, 1891.
George W. Bean . . .	Androscoggin Mills	Lewiston, Me.	Apr. 17, 1872.
Truman Beckwith . . .	Dyerville Manufg. Co.	Providence, R. I. . .	Apr. 17, 1892.
William W. Blades . .	Crefeld Mills	Westerly, R. I. . . .	Oct. 25, 1893.
N. B. Borden	Barnard Manufg. Co.	Fall River, Mass. . .	Oct. 15, 1873.
Richard B. Borden . .	Richard Borden Manufg. Co.	Fall River, Mass. . .	July 26, 1865.
Thomas J. Borden . .	Fall River Mutual Ins. Co. . .	Fall River, Mass. . .	July 26, 1865.
Thomas S. Borden . .	Metacomet Mills	Fall River, Mass. . .	Oct. 31, 1877.
E. S. Boss	Willimantic Linen Co.	Willimantic, Conn. . .	Oct. 29, 1879.
Stephen N. Bourne . .	Stark Mills	Manchester, N. H. . .	Oct. 21, 1868.
Ernest Bridge	Jas. Chadwick & Bro. Ltd. . . .	Jersey City, N. J. . .	Apr. 24, 1895.
Walter D. Brigham . .	Willimantic Linen Co.	Willimantic, Conn. . .	Apr. 24, 1895.
O. S. Brown	Salmon Falls Manufg. Co. . . .	Salmon Falls, N. H. .	Apr. 21, 1875.
E. C. Bucklin	Interlaken Mills	Providence, R. I. . .	Apr. 25, 1883.
Robert Burgess	140 State St.	New Bedford, Mass. .	Apr. 27, 1892.
Edward N. Burke . . .	Lowell Machine Shop.	Lowell, Mass.	Apr. 29, 1880.
W. R. Burnham . . .	Uncasville Manufg. Co.	Norwich, Conn. . . .	Apr. 29, 1885.
William D. Cadwell . .	Jackson & Nashua Companies .	Nashua, N. H. . . .	Apr. 19, 1871.
Byron F. Card	New Bedford Manufg. Co. . .	New Bedford, Mass. .	Apr. 25, 1888.
Arnold B. Chace, Jr. . .	Valley Falls Co.'s Woonsocket Mill		
	. . . . .	Valley Falls, R. I. . .	Apr. 24, 1895.
George A. Chace . . .	Bourne Mills	Fall River, Mass. . .	Apr. 25, 1877.
H. S. Chadwick	Dover Yarn Mill	Charlotte, N. C. . . .	Apr. 24, 1895.
Chauncey C. Chase . .	Attawaugan Mills	Killingly, Conn. . . .	Apr. 26, 1893.
Simeon B. Chase . . .	King Philip Mills	Fall River, Mass. . . .	Apr. 21, 1875.
Clarence N. Childs . .	Hamilton Manufg. Co.	Lowell, Mass.	Apr. 24, 1895.
Elmer G. Child	Agt. Boston Duck Co.	Bondsville, Mass. . .	Oct. 26, 1892.
George A. Clark . . .	Manchester Mills	Manchester, N. H. . .	Oct. 25, 1882.
Jeremiah Clark	Textile Machinery	Lowell, Mass.	Oct. 15, 1873.
J. William Clark . . .	Clark Thread Co.	Newark, N. J.	Oct. 26, 1892.
Alfred Clarke	Eastern Electric Light and Storage Battery Co. . . .		
	. . . . .	Lowell, Mass.	Apr. 30, 1879.
F. E. Clarke	Pemberton Co.	Lawrence, Mass. . .	July 26, 1865.
Alonzo A. Coburn . . .	Whitehead Machine Co. . . .	Lowell, Mass.	Apr. 25, 1888
J. G. Coburn	. . . . .	Newton, Mass	July 26, 1865.
John A. Collins	American Linen Co.	Fall River, Mass. . .	Oct. 31, 1883.
Frank B. Comins . . .	Aerphor Co.	Providence, R. I. . .	Oct. 28, 1891.
J. J. Connell	Cohannet Mills	Taunton, Mass. . . .	Apr. 27, 1892.

A. S. Covel	Tremont and Suffolk Mills	Boston, Mass.	Oct. 31, 1877.
A. G. Cumnock	Boott Cotton Mills	Lowell, Mass.	Oct. 28, 1885.
Andrew J. Currier	Albion Mills	Albion, R. I.	Apr. 25, 1888.
Woodbury K. Dana	Banner Mill	Saccarappa, Me.	Apr. 25, 1888.
A. W. Danforth	Shanghai Cot. Cloth Mill Co. 881 Bridge St.	Shanghai, China Lowell, Mass	Apr. 27, 1881.
A. Lockwood Danielson,	Quinebaug Co.	Providence, R. I.	Sept. 27, 1894.
J. DeForest Danielson	Lockwood Co.	Providence, R. I.	Sept. 27, 1894.
John W. Danielson	Quinebaug Co.	Providence, R. I.	July 15, 1868.
B. D. Davol		Fall River, Mass.	Apr. 25, 1877.
James C. Deane	Griswoldville Manufg. Co.	Griswoldville, Mass.	Apr. 25, 1894.
William P. Dempsey	Dempsey Bleachery	Pawtucket, R. I.	Apr. 28, 1886.
Charles W. Dennett	Johnson Manufg. Co.	North Adams, Mass.	Oct. 29, 1890.
E. P. Dennis	Lowell Machine Shop.	Lowell, Mass.	Apr. 25, 1888.
Charles A. Denny	American Card Clothing Co.	Leicester, Mass.	Apr. 25, 1888.
Chas. Owen Dexter	Canadian Col'd. Cot. Mills, Ltd.	Hamilton, Ont.	Apr. 24, 1895.
George Dexter,	Pepperell and Laconia Cos.	Boston, Mass.	Oct. 31, 1877.
Chas. C. Diman,	Whitman Mills	New Bedford, Mass.	Apr. 24, 1895.
Albert W. Dimick	Atlantic Cotton Mills	Lawrence, Mass.	Apr. 25, 1894.
Eben S. Draper	Geo. Draper & Sons.	Hopedale, Mass.	Oct. 31, 1888.
George A. Draper	Geo. Draper & Sons.	Hopedale, Mass.	Oct. 31, 1888.
George Otis Draper	Geo. Draper & Sons	Hopedale, Mass.	Apr. 24, 1895.
William F. Draper	Geo. Draper & Sons.	Hopedale, Mass.	Jan. 17, 1867.
William F. Draper, Jr.	Geo. Draper & Sons.	Hopedale, Mass.	Oct. 29, 1890.
Joseph M. Dunham	Merrick Thread Co.	Holyoke, Mass.	Oct. 26, 1892.
David H. Dyer	Quequechan Mills	Fall River, Mass.	Oct. 18, 1871.
William A. Eastman	Lowell Hosiery Co.	Lowell, Mass.	Sept. 27, 1894.
Russell W. Eaton	Cabot Manufg. Co.	Brunswick, Me.	Oct. 26, 1887.
John Eccles	Ponemah Mills	Taftville, Conn.	Apr. 27, 1892.
D. M. Ehrlich	Galveston C. and W. Mills	Galveston, Texas.	Apr. 24, 1895.
Lawrence V. Elder	Galveston C. and W. Mills	Galveston, Texas.	Oct. 27, 1886.
Frederick W. Ely	Columbian Manufg. Co.	Greenville, N. H.	Apr. 25, 1888.
H. B. Estes	Continental Mills	Lewiston, Me.	Apr. 26, 1893.
Herbert R. Farnum	Bernon Manufg. Co.	Georgiaville, R. I.	Apr. 27, 1881.
Clifton L. Field	Lowell Hosiery Co.	Lowell, Mass.	Apr. 25, 1894.
William Firth	American Drosophore Co.,	Boston, Mass.	Apr. 25, 1888.
Charles H. Fish	P. C. Cheney Co.	Manchester, N. H.	Apr. 27, 1887.
Herbert Fisher	Mason Machine Works	Taunton, Mass.	Oct. 29, 1879.
William B. Fittz	West Boylston Manufg. Co.,	Oakdale, Mass.	Oct. 26, 1892.
Frederick A. Flather	Lowell Machine Shop	Lowell, Mass.	Apr. 29, 1891.
M. F. Foster	Denison Cotton Manufg. Co.	Milford, N. H.	Apr. 17, 1872.
Philip H. Fowler	Gloucester Gingham Mills	Gloucester, N. J.	Nov. 30, 1881.
C. H. Frisbie	Attawaugan Mills	Norwich, Conn.	Oct. 29, 1890.

William Gammell	Berkeley Co.	Providence, R. I.	Oct. 28, 1885.
James G. Garland		Biddeford, Me.	Oct. 29, 1879.
Richard Garsed	Wingohocking Mills	Philadelphia, Penn.	Apr. 17, 1872.
James A. Gary	Alberton Cotton Mills	Baltimore, Md.	Apr. 25, 1883.
John Gegenheimer	Boston Duck Co.	Bondsville, Mass.	Apr. 30, 1890.
Charles E. Getchell	44 Snell St.	Brockton, Mass.	Oct. 30, 1889.
William C. Godfrey	Indian Orchard Mills	Indian Orchard, Mass.	Oct. 29, 1890.
Alfred M. Goodale	Boston Manufg. Co.	Boston, Mass.	Apr. 25, 1883.
Charles J. Goodwin	Indian Orchard Mills.	Indian Orchard, Mass.	Oct. 18, 1871.
Charles H. Gorton	Ballou Mill	Woonsocket, R. I.	Apr. 25, 1894.
William B. Gowdey	Mill Supplies.	Providence, R. I.	Apr. 30, 1890.
George P. Grant	Green and Daniels Manufg. Co.	Pawtucket, R. I.	Sept. 27, 1894.
George P. Grant, Jr.	Grant Yarn Co.	Fitchburg, Mass.	Sept. 27, 1894.
D. W. Gray	Skenandoa Cotton Co.	Utica, N. Y.	Oct. 26, 1892.
R. A. Gray	Rodman Manufg. Co.	Allenton, R. I.	Apr. 24, 1895.
Stephen Greene	Mill Engineer	Boston, Mass.	Oct. 27, 1886.
William C. Greene	Peacedale Manufg. Co.	Peacedale, R. I.	Oct. 27, 1886.
John Gregson	Merchants Manufg. Co.	Fall River, Mass.	Apr. 24, 1895.
Frederick Grinnell	General Fire Extinguisher Co.	Providence, R. I.	Apr. 24, 1878.
Arthur H. Gulliver	Lonsdale Co.	Ashton, R. I.	Apr. 24, 1889.
B. F. Guy	Pelzer Manufg. Co.	Pelzer, S. C.	Apr. 24, 1895.
Frank R. Hadley	Bennett Manufg. Co.	New Bedford, Mass.	Oct. 28, 1891.
Frank J. Hale	Pettee Machine Works	Newton Upper Falls, Mass.	Apr. 27, 1892.
Samuel Hale	Portsmouth Co.	South Berwick, Me.	Oct. 29, 1890.
William E. Hall	Boston Duck Co.	Bondsville, Mass.	Apr. 27, 1892.
Z. D. Hall	Berkshire Cotton Manufg. Co.	Adams, Mass.	Oct. 29, 1879.
John H. Hambly	Quidnick Manufg. Co.	Providence, R. I.	Apr. 24, 1895.
John F. Hamlet	Manchaug Co.	Manchaug, Masss.	Oct. 31, 1888.
J. O. Hannum	Saratoga Victory Mfg. Co.	Victory Mills, N. Y.	Apr. 30, 1890.
Frank Harris	Hamlet Mills	Woonsocket, R. I.	Apr. 24, 1889.
Henry F. Harris	West Boylston Manufg. Co.	Worcester, Mass.	Apr. 30, 1890.
John J. Hart	Merrimack Print Works	Lowell, Mass.	Apr. 24, 1895.
Frank Haskell	Westbrook Manufg. Co.	Westbrook, Me.	Apr. 25, 1883.
A. M. Hathaway	H. N. Slater Mills	Webster, Mass.	Sept. 27, 1894.
William Hathaway	Barnard Manufg. Co.	Fall River, Mass.	Apr. 25, 1894.
Alfred Hawkesworth	B. B. & R. Knight's Mill	Pontiac, R. I.	Apr. 26, 1893.
Horace L. Hayden	Walhalla Cotton Mills.	Walhalla, S. C.	Apr. 24, 1895.
William Hayes	Barker Mill	Auburn, Me.	Apr. 30, 1879.
James G. Hill	Lawrence Manufg. Co.	Lowell, Mass.	Jan. 15, 1868.
William R. Hill	Glasgow Manufg. Co.	S. Hadley Falls, Mass.	Oct. 25, 1893.
John H. Hines	Queen City Cotton Co.	Burlington, Vt.	Sept. 27, 1894.
Charles H. Hobbs	Thorndike Co.	Thorndike, Mass.	Apr. 28, 1886.
John Holland	Cocheco Manufg. Co.	Dover, N. H.	Oct. 31, 1877.
Gideon F. Holmes	Plymouth Cordage Co.	No. Plymouth, Mass.	Oct. 30, 1889.
George W. Holt	Monohansett Manufg. Co.	Putnam, Conn.	Oct. 29, 1879.

William P. Holt	Slatersville Mills	Slatersville, R. I.	Oct. 25, 1893.
George L. Hooper	Shaw Stocking Co.	Lowell, Mass.	Apr. 25. 1892.
John Hopkinson		Stamford, Ky.	Apr. 25, 1883.
Henry S. Houghton, Jr.	Paul Whitin Manufg. Co.	Northbridge, Mass.	Apr. 24, 1895.
Elisha H. Howard	Harris Manufg. Co.	Providence, R. I.	Apr. 25, 1883.
Henry S. Howe	Lawrence & Co.	Boston, Mass.	Oct. 31, 1877.
W. S. Hume	Tremont and Suffolk Mills	Lowell, Mass.	Oct. 29, 1890.
Arthur W. Hunking	Mass. Mills, in Georgia	Rome, Ga.	Apr. 24, 1895.
J. E. Jenckes	E. Jenckes Co.,	Pawtucket, R. I.	Apr. 24, 1895.
David L. Jewell	China, Webster & Pembroke M.	Suncook, N. H.	July 26, 1865.
William C. Jillson	Hop River Manufg. Co.	Willimantic, Conn.	Apr. 15, 1874.
David S. Johnston	Cohoes Fdy. & Machine Co.	Cohoes, N. Y.	Oct. 28, 1891.
W. E. Keach	57 Harrison St.	Pawtucket, R. I.	Oct. 26, 1892.
Roland R. Kelly	Williamstown Manufg. Co.	Williamstown, Mass.	Nov. 30, 1881.
Joseph H. Kendrick	American Supply Co.	Providence, R. I.	Apr. 30, 1879.
George E. Kent	Pittsfield, Mills	Pittsfield, N. H.	Oct. 31, 1888.
Hervey Kent	Exeter Manufg. Co.	Exeter, N. H.	July 26, 1865.
William J. Kent	Wamsutta Mills	New Bedford, Mass.	Oct. 26, 1887.
Nathaniel B. Kerr	Grinnell Manufg. Co.	New Bedford, Mass.	Oct. 26, 1892.
John Kilburn	Lawrence Manufg. Co.	Belmont, Mass.	July 26, 1865.
John M. Kimball	Slatersville Mills	Slatersville, R. I.	Oct. 31, 1888.
Albert F. Knight	Amory Manufg. Co.	Manchester, N. H.	Oct. 27, 1886.
Albert Knight	Quidnick Manufg. Co.	Anthony, R. I.	Apr. 25, 1895.
Jesse A. Knight	Enfield Mills.	Enfield, R. I.	Oct. 26. 1892.
Stephen A. Knight	Hebron Manufacturing Co.	Providence, R. I.	Oct. 21, 1868.
Walter B. Knight	Reynolds Manufg. Co.	Davisville, R. I.	Apr. 24, 1889.
Fred Lacey	Greylock Mills	North Adams, Mass.	Apr. 24, 1895.
Abbott F. Lawrence	Nemasket Mills	Taunton, Mass.	Apr. 24, 1895.
Harold Lawton		Centreville, R. I.	Oct. 27, 1886.
Evan Arthur Leigh	E. A. Leigh & Co.	Boston, Mass.	Oct. 29, 1890.
J. Colby Lewis	Centerville Cotton Mills	Centerville, R. I.	Oct. 26, 1892.
Charles W. Lippitt	Social Manufg. Co.	Providence, R. I.	Oct. 30, 1878.
Henry F. Lippitt	Globe Mill	Providence, R. I.	Apr. 27, 1881.
Robert W. Lord	R. W. Lord & Co.	Kennebunk, Me.	Oct. 20, 1869.
Ernest Lovering	Lyman Mills	Holyoke, Mass.	Apr. 25, 1888.
Henry M. Lovering	Whittenton Manufg. Co.	Taunton, Mass.	Oct. 27, 1880.
William M. Lovering	Whittenton Mills.	Taunton, Mass.	Sept. 27, 1894.
Arthur H. Lowe	Parkhill Manufg. Co.	Fitchburg, Mass.	Oct. 30, 1889.
David Lowe	Parkhill Manufg. Co.	Fitchburg, Mass.	Apr. 24, 1895.
J. S. Ludlam	Merrimack Manufg. Co.	Lowell, Mass.	Apr. 21, 1875.
William L. Lyall	J. & W. Lyall	New York City	Oct. 26, 1892.
Alvin S. Lyon	Lowell Manufg. Co.	Lowell, Mass.	Apr. 26, 1882.
Jas. R. MacColl	Lorraine Manufg. Co.	Pawtucket, R. I.	Apr. 24, 1895.

Chas. L. Macomber	Nemasket Mills	Taunton, Mass.	Apr. 24, 1895.
Charles T. Main	Mill Engineer.	Boston, Mass.	Oct. 28, 1885.
Charles R. Makepeace	Mill Engineer.	Providence, R. I.	Apr. 30, 1890.
Arthur B. Mann	U. S. Cotton Co.	Central Falls, R. I.	Apr. 25, 1894.
Charles H. Manning	Amoskeag Manufg. Co.	Manchester, N. H.	Oct. 28, 1885.
Henry F. Mansfield	Utica Steam Cotton Mills.	Utica, N. Y.	Apr. 30, 1890.
Albert G. Martin	Kincaid Manufg. Co.	Griffin, Ga.	Apr. 30, 1884.
Ira J. Martin	Bozrahville Co.	Bozrahville, Conn.	Oct. 26, 1892.
Philip A. Mathewson	Chace Mills	Fall River, Mass.	Apr. 24, 1895.
Rufus A. Maxfield		Lowell, Mass.	Apr. 17, 1872.
Thomas Mayor	Textile Machinery	Providence, R. I.	Oct. 27, 1880.
Robert McArthur	Pepperell and Laconia Cos.	Biddeford, Me.	Apr. 17, 1872.
Charles D. McDuffie	Manchester Mills	Manchester, N. H.	Apr. 21, 1869.
Fred C. McDuffie	Everett Mills	Boston, Mass.	Oct. 25, 1882.
William E. McGill		Philadelphia, Penn.	Apr. 27, 1892.
William G. McLoon	Boston Manufg. Co.	Waltham, Mass.	Apr. 27, 1892.
James H. McMullan	Saco Water Power Machine Co.	Biddeford, Me.	Apr. 21, 1869.
William P. McMullan	Naumkeag Steam Cotton Co.	Salem, Mass.	Sept. 27, 1894.
John Tempest Meats	Mason Machine Works	Taunton, Mass.	Apr. 27, 1887.
Charles H. Merriman, Jr.	Social Co.	Woonsocket, R. I.	Apr. 25, 1895.
Frank M. Messenger	Grosvenor Dale Co.	No. Grosvenor Dale, Conn.	Apr. 27, 1887.
James I. Milliken	Everett Mills	Lawrence, Mass.	Oct. 26, 1892.
A. B. Mole	W. C. Plunkett & Sons,	Adams, Mass.	Apr. 24, 1895.
Edward A. Mongeon	Blackstone Manufg. Co.	Blackstone, Mass.	Apr. 24, 1895.
Fred W. Moore	Cordis Mills	Millbury, Mass.	Apr 27, 1892.
George F. Morgan	Lowell Machine Shop	Lowell, Mass.	Oct. 28, 1891.
Albert H. Morton	Kitson Manufg. Co.	Lowell, Mass.	Oct. 28, 1891.
Oliver H. Moulton	Hamilton Manufg. Co.	Lowell, Mass.	July 26, 1865.
Joseph A. Moyes	Androscoggin Mills	Lewiston, Me.	Apr. 25, 1894.
Farquharson J. Muir	Canadian Col. Cotton Mills Co.	Hamilton, Ont., Can.	Apr. 27, 1892.
William G. Nichols	Glasgow Manufg. Co.	S. Hadley Falls, Mass.	Oct. 25, 1893.
Franklin Nourse	Lawrence Manufg. Co.	Lowell, Mass.	Apr. 24, 1878.
Eben H. Nutting	Hooksett Manufg. Co.	Hooksett, N. H.	Oct. 25, 1882.
S. Odenheimer	Lane Mills	New Orleans, La.	Oct. 25, 1893.
Charles K. Oliver	Columbia Mills Co.	Columbia, S. C.	Sept. 27, 1894.
Warren M. Orswell	Shirley Yarn Co.	Fitchburg, Mass.	Apr. 16, 1873.
Oscar L. Owen	Whitin Machine Works	Whitinsville, Mass.	Apr. 25, 1894.
Elmer E. Page	York Manufg. Co.	Saco, Me.	Apr. 27, 1892.
Francis J. Parker	Monadnock Mills	Boston, Mass.	Jan. 15, 1868.
Frank W. Parker	Lewiston Mills	Lewiston, Me.	Apr. 25, 1894.
O. B. Parker	U. S. Cotton Co.	Central Falls, R. I.	Apr. 24, 1895.
Walter E. Parker	Pacific Mills	Lawrence, Mass.	Apr. 25, 1877.
John H. Parks	New Brunswick Cotton Mills	St. John, N. B.	Apr. 24, 1878.
John W. Pead	Merrimack Manufg. Co.	Lowell, Mass.	Apr. 26, 1893.
Andrew G. Peirce, Jr.,	Peirce Manufg. Corp.	New Bedford, Mass.	Apr. 24, 1895.

William D. Pennell	Hill Manufg. Co.	Lewiston, Me.	Apr. 16, 1873.
Haven C. Perham	Kitson Machine Co.	Lowell, Mass.	Apr. 30, 1879.
Henry C. Philips	Sutton Manufg. Co	Wilkinsonville, Mass.	Apr. 25, 1894.
Moses Pierce	Aspincook Co.	Jewett City, Conn.	Oct. 30, 1878.
Wm. C. Peirce	Elizabeth Mills	Providence, R. I.	Apr. 24, 1895.
Charles H. Plummer	Great Falls Manufg. Co.	Somersworth, N. H.	Apr. 25, 1888.
Thomas C. Powell	Slatersville Mills	Providence, R. I.	Oct. 30, 1889.
Herbert L. Pratt	Bates Manufg. Co.	Lewiston, Me.	Oct. 27, 1875.
J. E. Prest	Harmony Mills.	Cohoes, N. Y.	Apr. 17, 1872.
M. W. Quinn	Hamilton Woolen Co.	Amesbury, Mass.	Oct. 27, 1886.
T. G. Ramsdell	Monument Mills	Housatonic, Mass.	Oct. 30, 1878.
M. A. Rawlinson	Tremont and Suffolk Mills	Lowell, Mass.	Apr. 24, 1895.
Robert Redford	Arlington Mills	Lawrence, Mass.	Apr. 26, 1882.
James Renfrew	Renfrew Manufg. Co.	Adams, Mass.	Oct. 18, 1871.
Roscoe C. Reynolds	Lewiston Machine Co.	Lewiston, Me.	Oct. 25, 1876.
F. H. Rice	Holbrook Mills	W. Boylston, Mass.	Apr. 29, 1880.
C. H. Richardson	Appleton Co.	Lowell, Mass.	Apr. 24, 1889.
Charles E. Riley	Textile Machinery	Boston, Mass.	Apr. 25, 1888.
Charles D. Robinson	Crompton Co.	Crompton, R. I.	Sept. 27, 1894.
John K. Russell	May's Landing Water P. Co.	Vineland, N. J.	Apr. 30, 1884.
Arnold B. Sanford	Globe Yarn Mill	Fall River, Mass.	Oct. 25, 1882.
Charles H. Savage	Manville Co.	Manville, R. I.	Apr. 26, 1893.
J. H. Sawyer	Newmarket Manufg. Co.	Boston, Mass.	July 26, 1865.
G. H. Sayward	Standard Yarn Co.	Oswego, N. Y.	Oct. 29, 1890.
Arnold Schaer	Warren Manufg. Co.	Warren, R. I.	Apr. 24, 1895.
John Scott	Willimantic Linen Co.	Willimantic, Conn.	Oct. 29, 1879.
Frank P. Sheldon	Mill Engineer.	Providence, R. I.	Apr. 25, 1894.
Thomas C. Sheldon	Fitchburg Duck Mills	Fitchburg, Mass.	Oct. 29, 1884.
George E. Sherman		Valley Falls, R. I.	Apr. 27, 1881.
William F. Sherman	Atlantic Cotton Mills	Lawrence, Mass.	Apr. 15, 1874.
Charles M. Shove	Granite Mills	Fall River, Mass.	Oct. 27, 1875.
Herbert H. Shumway	B. B. & R. Knight	Providence, R. I.	Apr. 24, 1895.
Francis H. Silsbee	Pacific Mills	Lawrence, Mass.	Apr. 27, 1887.
Louis Simpson	Montreal Cotton Co.	Valleyfield, P. Q.	Apr. 24, 1895.
Abbott E. Slade	Laurel Lake Mills	Fall River, Mass.	Oct. 25, 1893.
Arba C. Slater	Linwood Mills	Whitinsville, Mass	Jan. 15, 1868.
Robert R. Smith	Greenwoods Co.	New Hartford, Conn	Oct. 19, 1870.
Ellison A. Smyth	Pelzer Manufg. Co.	Pelzer, S. C.	Oct. 26, 1892.
Wm. S. Southworth	Mass. Cotton Mills	Lowell, Mass.	Oct. 31, 1888.
William I. Spear	Jackson Co.	Nashua, N. H.	Oct. 30, 1889.
S. S. Spencer	Conestoga Steam Mills	Lancaster, Penn.	Oct. 25, 1876.
George R. Stearns	Riverside Mills	Augusta, Ga.	Apr. 30, 1890.
Joseph Stone	53 State Street.	Boston, Mass.	Oct. 21, 1874.
Herman F. Straw	Amoskeag Manufg. Co.	Manchester, N. H.	Oct. 28, 1885.

W. H. Summersby	B. B. & R. Knight.	Pontiac, R. I.	Oct. 25, 1893.
Albert A. Sweet	King Philip Mills	Fall River, Mass.	Apr. 24, 1895.
James O. Sweet	Ashland Cotton Co.	Jewett City, Conn.	Apr. 28, 1886.
Edward P. Taft	Ponemah Mills	Providence, R. I.	Oct. 28, 1885.
Robert Rennie Taft	Baltic Mills	Baltic, Conn.	Apr. 24, 1895.
Robert W. Taft	Coventry Co.	Providence, R. I.	Sept. 27, 1894.
George P. Taylor	Lancaster Mills	Clinton, Mass.	Apr. 25, 1877.
James W. Taylor	Canoe River Mills	Taunton, Mass.	Oct. 26, 1892.
Richard Thackeray	Weetamoe Mills	Fall River, Mass.	Apr. 29, 1885.
Earl A. Thissell	Central Oil Gas Stove Co.	Florence, Mass.	Oct. 30, 1878.
Ariel C. Thomas	Clinton Manufg. Co.	Woonsocket, R. I.	Oct. 31, 1888.
Charles E. Thomas	Forestdale Manufg. Co.	Woonsocket, R. I.	Oct. 31, 1883.
Edward W. Thomas	Tremont and Suffolk Mills	Lowell, Mass.	Apr. 30, 1884.
Ralph E. Thomson	Parkhill Manufg. Co.	Fitchburg, Mass.	Apr. 25, 1894.
D. M. Thompson	Corliss Steam Engine Co.	Providence, R. I.	Oct. 28, 1885.
Osmon B. Tilton	Lynchburg Cotton Mills	Lynchburg, Va.	Oct. 27, 1886.
James P. Tolman	Samson Cordage Works	Boston, Mass.	Oct. 29, 1890.
George W. Towne	Arlington Mills	Lawrence, Mass.	Oct. 26, 1892.
William E. Trainer	Linwood Mills	Trainer, Penn.	Apr. 21, 1875.
Robert B. Treat	Centerville Cotton Mill	Centerville, R. I.	Sept. 27, 1894.
Edmund E. Truesdell	China, Webs'r & Pemb'ke M.	Suncook, N. H.	Apr. 26, 1876.
Oscar B. Truesdell	Fiskdale Mills	Fiskdale, Mass.	Apr. 24, 1895.
Frank P. Vogl	Monadnock Mills	Claremont, N. H.	Sept. 27, 1894.
Jude C. Wadleigh	Mass. Cotton Mills	Lowell, Mass.	Oct. 26, 1892.
H. E. Walmesley	Clark Thread Co.	Newark, N. J.	Oct. 29, 1890.
James A. Walsh	Lewiston Bleachery	Lewiston, Me.	Apr. 27, 1892.
James Waring	Narragansett Mills	Fall River, Mass.	Oct. 27, 1875.
John Waterman	Warren Manufg. Co.	Warren, R. I.	Apr. 30, 1884.
J. W. Wattles	Supplies	Canton, Mass.	July 26, 1865.
T. B. Wattles	Boscawen Mills	Penacook, N. H.	July 26, 1865.
George W. Weeks	Lancaster Mills	Clinton, Mass.	Apr. 21, 1869.
W. B. Smith Whaley	Richland Cotton Mills	Columbia, S. C.	Apr. 24, 1895.
H. D. Wheat	Gaffney Manufg. Co.	Gaffney, S. C.	Apr. 24, 1895.
Channing Whitaker	Mill Engineer	Tyngsborough, Mass.	Oct. 15, 1873.
A. Tenny White	Globe Mill	Woonsocket, R. I.	Oct. 26, 1887.
Arthur F. Whitin	Sanders Cotton Mills / Whitinsville Cotton Mills	Whitinsville, Mass.	Apr. 24, 1895.
Henry T. Whitin	Paul Whitin Manufg. Co.	Northbridge, Mass.	Apr. 25, 1877.
Alfred N. Whiting	L. M. Harris Manufg. Co.	Oakdale, Mass.	Apr. 21, 1875.
William S. Whitney		Fall River, Mass.	Apr. 24, 1878.
William Whittam, Jr.	Jas. Chadwick & Bro., Ltd.	Jersey City, N. J.	Apr. 26, 1893.
George F. Whitten	Stark Mills	Manchester, N. H.	Oct. 26 1892.
E. B. Wilbur	Pequot Mills	Montville, Conn.	Oct. 30, 1889.
Henry M. Wilcox	John Rhodes Warp Mill	Millbury, Mass.	Apr. 24, 1889.

Theop. W. Wilmarth	Millbury Cotton Mills	Millbury, Mass.	Oct. 31, 1883.
Thomas Wilmarth	Saunders Cotton Mills	Saundersville, Mass.	Apr. 21, 1875.
A. S. Winslow	Crompton Co.	Crompton, R. I.	Oct. 31, 1888.
George Wood	Millville Manufg. Co.	Philadelphia, Penn.	Oct. 16, 1872.
C. J. H. Woodbury	Secretary and Treasurer	Lynn, Mass.	Oct. 29, 1879.
Alvin Woodman	Jewett City Mills	Jewett City, Conn.	Apr. 26, 1893.
A. A. Young, Jr.	Jewett City Mills	Jewett City, Conn.	Sept. 27, 1894.
Adelbert R. Young	Ashland Cotton Co.	Jewett City, Conn.	Apr. 25, 1894.

ASSOCIATE MEMBERS.

G. M. Angier	Mather Electric Co.	Boston, Mass.	Apr. 24, 1895.
Geo. R. Babbitt	American Oil Co.	Providence, R. I.	Apr. 24, 1895.
Geo. S. Barnum	Bigelow Co.	New Haven, Conn.	Apr. 24, 1895.
Geo. W. Benson	Cotton Dealer	Boston, Mass.	Apr. 24, 1895.
J. Payson Bradley	The Kehew-Bradley Co.	Boston, Mass.	Apr. 24, 1895.
D. Russell Brown	Brown Bros. Co.	Providence, R. I.	Apr. 24, 1895.
H. Martin Brown	Brown Bros. Co.	Providence, R. I.	Apr. 24, 1895.
John H. Burghardt	Mill Supplies	Boston Mass.	Apr. 24, 1895.
James Butterworth	H. W. Butterworth & Sons	Philadelphia, Pa.	Apr. 24, 1895,
Malcolm Campbell	Woonsocket Machine and Press Co.	Woonsocket, R. I.	Apr. 24, 1895.
W. W. Carey	Machinery Builder	Lowell, Mass.	Apr. 24, 1895.
Fred A. Chase	Mill Supplies	Providence, R. I.	Apr. 24, 1895.
Chas. H. Childs	Brown Bros. Co.	Providence, R. I.	Apr. 24, 1895.
Peter H. Corr	Cotton and Cotton Yarns	Taunton, Mass.	Apr. 24, 1885.
Thomas S. Cox	Mason Machine Works	Taunton, Mass.	Apr. 24, 1895.
Frederick I. Dana	Thomas Phillips Co.	Providence, R. I.	Apr. 25, 1895.
R. H. Deming	Cotton	Providence, R. I.	Apr. 24, 1895.
C. E. W. Dow	Metallic Roll Co.	Indian Orchard, Mass.	Apr. 24, 1895.
Wm. H. Dyer	Reeds	Providence, R. I.	Apr. 24, 1895.
T. C. Entwistle	Cotton Machinery	Lowell, Mass.	Apr. 24, 1895.
D. D. Felton	S. A. Felton & Sons	Manchester, N. H.	Apr. 24, 1895.
John W. Fergurson	Mill Engineer	Paterson, N. J.	Apr. 24, 1895.
J. Herbert Foster	Cotton	Providence, R. I.	Apr. 24, 1895.
Geo. A. Fuller	Stedman & Fuller Mfg. Co.	Providence, R. I.	Apr. 24, 1895.
Allan V. Garratt	Lombard Water Wheel Gov. Co.	Boston, Mass.	Apr. 24, 1895.
Royal W. Gates	Joshua Gates & Sons, Belting	Lowell, Mass.	Apr. 24, 1895.
W. S. Granger	Granger Foundry & Machine Co.	Providence, R. I.	Apr. 24, 1895.
Walter S. Hackney	Gen. Fire Extinguisher Co.	Providence, R. I.	Apr. 25, 1895.
Wm. B. Hawes	Cotton Yarn Broker	Fall River, Mass.	Apr. 24, 1895.
David Jackson	Cotton Machinery	Pawtucket, R. I.	Apr. 25, 1895.
Wm. B. Kehew	The Kehew-Bradley Co.	Boston, Msas.	Apr. 24, 1895.

Josiah M. Lasell	Whitin Machine Works	Whitinsville, Mass.	Apr. 24, 1895.
F. H. Maynard	Gen. Fire Extinguisher Co.	Providence, R. I.	Apr. 24, 1895.
Geo. H. Meader	Steam Appliances	Boston, Mass.	Apr. 24, 1895.
Geo. B. Morison	Hadley Co.	Boston, Mass.	Apr. 24, 1895.
Sidney B. Paine	General Electric Co.	Boston, Mass.	Apr. 24, 1895.
Geo. C. Phillips	Tape Dresser	Providence, R. I.	Apr. 24, 1895.
Stephen Minot Pitman	Narragansett Fire Ins. Co.	Providence, R. I.	Apr. 25, 1895.
Charles F. Randall	Expert in Textiles	Boston, Mass.	Apr. 25, 1895.
R. H. Rice	Rice & Sargent St'm Engine Co.	Providence, R. I.	Apr. 24, 1895.
C. E. Roberts	Hartford St. Boiler Insp. & Ins. Co.	Boston, Mass.	Apr. 24, 1895.
Henry C. Spence	Metallic Drawing Roll Co.	Indian Orchard, Mass.	Apr. 24, 1895.
George W. Stafford	Knowles Loom Works	Providence, R. I.	Apr. 25, 1895.
Daniel J. Sully	Cotton Broker	Providence, R. I.	Apr. 24, 1895.
Cyrus A. Taft	Whitin Machine Works	Whitinsville, Mass.	Apr. 24, 1895.
G. A. Thudium	Supplies	Boston, Mass.	Apr. 24, 1895.
Wm. V. Threlfall	Pettee Machine Works	Newton Upper Falls, Mass	Apr. 24, 1895.
G. Marston Whitin	Whitin Machine Works	Whitinsville, Mass.	Apr. 24, 1895.
Erving Y. Woolley,	152 Congress St.	Boston, Mass.	Apr. 24, 1895.

Honorary Members	2
Total number of Active Members	332
Total number of Associate Members	49
Total Membership	383

MEMBERS OF THE ASSOCIATION,

1895.

ARRANGED BY STATES.

MAINE.

Stephen I. Abbot	Lockwood Co.	Waterville.
A. D. Barker	Avon Manufg. Co.	Lewiston.
George W. Bean	Androscoggin Mills	Lewiston.
Woodbury K. Dana	Banner Mill	Saccarappa.
Russell W. Eaton	Cabot. Manufg. Co.	Brunswick.
H. B. Estes	Continental Mills	Lewiston.
James G. Garland		Biddeford.
Samuel Hale	Portsmouth Co.	South Berwick.
Frank Haskell	Westbrook Manufg. Co.	Saccarappa.
William Hayes	Barker Mill	Auburn.
Robert W. Lord	R. W. Lord & Co.	Kennebunk.
Robert McArthur	Pepperell and Laconia Cos.	Biddeford.
James H. McMullan	Saco Water Power Machine Co.	Biddeford.
Joseph A. Moyes	Androscoggin Mills	Lewiston.
Elmer E. Page	York Manufg. Co.	Saco.
Frank W. Parker	Lewiston Mills	Lewiston.
William D. Pennell	Hill Manufg. Co.	Lewiston.
Herbert L. Pratt	Bates Manufg. Co.	Lewiston.
Roscoe C. Reynolds	Lewiston Machine Co.	Lewiston.
James A. Walsh	Lewiston Bleachery	Lewiston.

NEW HAMPSHIRE.

Stephen N. Bourne	Stark Mills	Manchester.
O. S. Brown	Salmon Falls Manufg. Co.	Salmon Falls.
William D. Cadwell	Jackson Co.	Nashua.
George A. Clark	Manchester Mills	Manchester.
Frederick W. Ely	Columbian Manufg. Co.	Greenville.
D. D. Felton	S. A. Felton & Sons Co.	Manchester.
Charles H. Fish	P. C. Cheney Co.	Manchester.

M. F. Foster	Denison Cotton Manufg. Co.	Milford.
John Holland	Cocheco Manufg. Co.	Dover.
David L. Jewell	China, Webster & Pembroke Mills	Suncook.
George E. Kent	Pittsfield Mills	Pittsfield.
Hervey Kent	Exeter Manufg. Co.	Exeter.
Albert F. Knight	Amory Manufg. Co.	Manchester.
Charles H. Manning	Amoskeag Manufg. Co.	Manchester.
Charles D. McDuffie	Manchester Mills	Manchester.
Eben H. Nutting	Hooksett Manufg. Co	Hooksett.
Charles H. Plummer	Great Falls Manufg. Co.	Great Falls.
William I. Spear	Jackson Co.	Nashua.
Herman F. Straw	Amoskeag Manufg Co.	Manchester.
Edmund E. Truesdell	China, Webster & Pembroke Mills	Suncook.
Frank P. Vogl	Monadnock Mills	Claremont.
T. B. Wattles	Boscawen Mills	Pennacook.
George F. Whitten	Stark Mills	Manchester.

VERMONT.

John H. Hines	Queen City Cotton Co.	Burlington.

MASSACHUSETTS.

HONORARY MEMBER.

Ambrose Eastman	53 State St.	Boston.

Alfred E. Adams	Whitinsville Cotton Mills	Whitinsville.
F. S. Akin	Cornell Mills	Fall River.
George E. Ames	Supt. Lawrence Manufg. Co.	Lowell.
G. M. Angier	Mather Electric Co.	Boston.
Edward Atkinson	Boston Mfrs. Mutual Fire Ins. Co.	Boston.
Edward W. Atkinson	Stoddard, Haserick, Richards & Co.,	Boston.
George A. Ayer	Supt. City Manufg. Corp.	New Bedford.
Charles L. Bailey	Boston Manufg. Co.	Waltham.
Henry A. Bailey	Chicopee Manufg. Co.	Chicopee Falls.
Edward R. Ballou		New Bedford.
W. A. Barrell	Lawrence Duck Co.	Lawrence.
Edwin N. Bartlett	Sigourney Mill	North Oxford.
George W. Benson	Cotton Dealer	Boston.
Nathaniel B. Borden	Barnard Manufg. Co.	Fall River.
Richard B. Borden	Troy C. and W. Manufg. Co.	Fall River.
Thomas J. Borden	Fall River Mutual Ins. Co.	Fall River.
Thomas S. Borden	Metacomet Mills	Fall River.
J. Payson Bradley	The Kehew-Bradley Co.	Boston.
Robert Burgess	140 State St.	New Bedford.
John H. Burghardt	Mill Supplies	Boston.
Edward N. Burke	Lowell Machine Shop	Lowell.

Byron F. Card	New Bedford Manufg. Co.	New Bedford.
W. W. Carey	Machinery Builder	Lowell.
George A. Chace	Bourne Mills	Fall River.
Simeon B. Chase	King Philip Mills	Fall River.
Clarence N. Childs	Asst. Supt. Hamilton Manufg. Co.	Lowell.
Elmer G. Childs	Mass. Cotton Mills	Lowell.
Jeremiah Clark	Textile Machinery	Lowell.
Alfred Clarke	Eastern Elec. Light & Stor. Bat. Co.,	Lowell.
F. E. Clarke	Pemberton Co.	Lawrence.
Alonzo A. Coburn	Whitehead Machine Co.	Lowell.
J. G. Coburn		Newton.
John A. Collins	American Linen Co.	Fall River.
J. J. Connell	Cohannet Mills	Taunton.
Peter H. Corr	Cotton and Cotton Yarns	Taunton.
Alphonso S. Covel	Tremont and Suffolk Mills	Boston.
Thomas G. Cox	Mason Machine Works	Taunton.
A. G. Cumnock	Boott Cotton Mills	Lowell.
B. D. Davol		Fall River.
James C. Deane	Griswoldville Manufg. Co.	Griswoldville.
Chas. W. Dennett	Johnson Manufg. Co.	North Adams.
E. P. Dennis	Lowell Machine Shop.	Lowell.
Charles A. Denny	American Card Clothing Co.	Leicester.
George Dexter	Pepperell and Laconia Cos.	Boston.
Chas. C. Diman	Whitman Mills	New Bedford.
Albert W. Dimick	Atlantic Cotton Mills	Lawrence.
C. E. W. Dow	Metallic Roll Co.	Indian Orchard.
Eben S. Draper	Geo. Draper & Sons.	Hopedale.
George A. Draper	Geo. Draper & Sons.	Hopedale.
Geo. Otis Draper	Geo. Draper & Sons	Hopedale.
William F. Draper	Geo. Draper & Sons.	Hopedale.
William F. Draper, Jr.	Geo. Draper & Sons.	Hopedale.
Joseph M. Dunham	Merrick Thread Co.	Holyoke.
David H. Dyer	Quequechan Mills	Fall River.
William A. Eastman	Lowell Hosiery Co.	Lowell.
T. C. Entwistle	Manufacturer of Cotton Mach'y	Lowell.
Clifton L. Field	Lowell Hosiery Co.	Lowell.
William Firth	American Drosophore Co.	Boston.
Herbert Fisher	Mason Machine Works	Taunton.
William B. Fittz	West Boylston Manufg. Co.	Oakdale.
Frederick A. Flather	Lowell Machine Shop	Lowell.
Allan V. Garratt	Lombard Water Wheel Gov. Co.	Boston.
Royal W. Gates	Leather Belting	Lowell.
John Gegenheimer	Doston Duck Co.	Bondsville.
Charles E. Getchell	44 Snell Street	Brockton.
William C. Godfrey	Indian Orchard Mills	Indian Orchard.

Alfred M. Goodale	Boston Manufg. Co.	Boston.
Charles J. Goodwin	Indian Orchard Mills	Indian Orchard.
George P. Grant, Jr.	Grant Yarn Co.	Fitchburg.
Stephen Greene	Mill Engineer	Boston.
John Gregson	Merchant Manufg. Co.	Fall River.
Frank R. Hadley	Bennett Manufg. Co.	New Bedford.
Frank J. Hale	Pettee Machine Works	Newton Upper Falls.
William E. Hall	Lawrence Manufg. Co.	Lowell.
Z. D. Hall	Berkshire Cotton Manufg. Co.	Adams.
John F. Hamlet	Manchaug Co.	Manchaug.
Henry F. Harris	West Boylston Manufg. Co.	Worcester.
John J. Hart	Merrimack Print Works	Lowell.
A. M. Hathaway	H. N. Slater Mills	Webster.
Samuel E. Hathaway	Fall River Iron Works Mills.	Fall River.
William Hathaway	Barnard Manufg. Co.	Fall River.
William B. Hawes	Cotton Yarn Broker	Fall River.
Horace L. Hayden	Plymouth Woolen & Cotton Fact'y	Plymouth.
James G. Hill	Lawrence Manufg. Co.	Lowell.
William R. Hill	Glasgow Manufg. Co.	So. Hadley Falls.
Chas. H. Hobbs	Thorndike Co.	Thorndike.
Gideon F. Holmes	Plymouth Cordage Co.	North Plymouth.
Geo. L. Hooper	Shaw Stocking Co.	Lowell.
Henry S. Houghton, Jr.	Paul Whitin Mfg. Co.	Northbridge.
Henry S. Howe	Lawrence & Co.	Boston.
W. S. Hume	Tremont and Suffolk Mills	Lowell.
Wm. B. Kehew	The Kehew-Bradley Co.	Boston.
Roland R. Kelly	Williamstown Manufg. Co.	Williamstown.
William J. Kent	Wamsutta Mills	New Bedford.
Nathaniel B. Kerr	Grinnell Manufg. Co.	New Bedford.
John Kilburn	Lawrence Manufg. Co.	Belmont.
Fred Lacey	Greylock Mills	North Adams.
Josiah M. Lasell	Whitin Machine Works	Whitinsville.
Abbott F. Lawrence	Nemasket Mills	Taunton.
Evan Arthur Leigh	E. A. Leigh & Co.	Boston.
Ernest Lovering	Lyman Mills	Holyoke.
Henry M. Lovering	Whittenton Manufg. Co.	Taunton.
William M. Lovering.	Whittenton Manufg. Co.	Taunton.
Arthur H. Lowe	Parkhill Manufg. Co.	Fitchburg.
David Lowe	Parkhill Manufg. Co.	Fitchburg.
J. S. Ludlam	Merrimac Manufg. Co.	Lowell.
Alvin S. Lyon	Lowell Manufg. Co.	Lowell.
Chas. L. Macomber	Nemasket Mills	Taunton.
Charles T. Main	Mill Engineer	Boston.
Philip A. Mathewson	Chace Mills	Fall River.
Rufus A. Maxfield		Lowell.
Fred C. McDuffie	Everett Mills	Lawrence.

William G. McLoon	Boston Manufg. Co.	Waltham.
William P. McMullan,	Naumkeag Steam Cotton Co.	Salem.
Geo. H. Meader	Steam Appliances	Boston.
John Tempest Meats	Mason Machine Works	Taunton.
James I. Milliken	Everett Mills	Lawrence.
A. B. Mole	W. C. Plunkett & Sons	Adams.
Edward A. Mongeon	Blackstone Manufg. Co.	Blackstone.
Fred W. Moore	Cordis Mills	Millbury.
George F. Morgan	Tremont and Suffolk Mills	Lowell.
Geo. B. Morison	Hadley Co.	Boston.
Albert H. Morton	Kitson Manufg. Co.	Lowell.
Oliver H. Moulton	Hamilton Manufg. Co.	Lowell.
William G. Nichols	Glascow Manufg. Co.	South Hadley Falls.
Franklin Nourse	Lawrence Manufg. Co.	Lowell.
Warren M. Orswell	Shirley Yarn Co.	Fitchburg.
Oscar L. Owen	Whitin Machine Works	Whitinsville.
Sidney B. Paine	General Electric Co.	Boston.
Francis J. Parker	Monadnock Mills	Boston.
Walter E. Parker	Pacific Mills	Lawrence.
John W. Pead	Merrimac Manufg. Co.	Lowell.
Haven C. Perham	Kitson Machine Co.	Lowell.
Henry C. Phillips	Sutton Manufg. Co.	Wilkinsonville.
Andrew G. Peirce, Jr.	Peirce Manufg. Corp.	New Bedford.
M. W. Quinn	Hamilton Woolen Co.	Amesbury.
T. G. Ramsdell	Monument Mills	Housatonic.
Charles F. Randall	Expert in Textiles	Boston.
M. A. Rawlinson	Tremont and Suffolk Mills	Lowell.
Robert Redford	Arlington Mills	Lawrence.
James Renfrew	Renfrew Manufg. Co.	Adams.
F. H. Rice	Holbrook Mills	West Boylston.
Charles E. Riley	Textile Machinery	Boston.
C. E. Roberts	Hartford St. Boiler Insp. & Ins. Co.	Boston.
Arnold B. Sanford	Globe Yarn Mill	Fall River.
J. H. Sawyer	Newmarket Manufg. Co.	Boston.
Thomas C. Sheldon	Fitchburg Duck Mills	Fitchburg.
William F. Sherman,	Atlantic Cotton Mills	Lawrence.
Charles M. Shove	Granite Mills	Fall River.
Francis H. Silsbee	Pacific Mills	Lawrence.
Abbott E. Slade	Laurel Lake Mills	Fall River.
Arba C. Slater	Linwood Mills	Whitinsville.
William S. Southworth	Mass. Cotton Mills	Lowell.
Henry C. Spence	Metallic Drawing Roll Co.	Indian Orchard.
Joseph Stone	85 Milk St.	Boston.
Albert A. Sweet	King Philip Mills	Fall River.
Cyrus A. Taft	Whitinsville Machine Works	Whitinsville.
Geo. P. Taylor	Lancaster Mills	Clinton.

James W. Taylor	Canoe River Mills	Taunton.
Richard Thackeray	Weetamoe Mills	Fall River.
Earl A. Thissell	Central Oil Gas Stove Co.	Florence.
Edward W. Thomas	Tremont and Suffolk Mills	Lowell.
Ralph E. Thomson	Parkhill Manufg. Co.	Fitchburg.
Wm. V. Threlfall	Pettee Machine Works	Newton Upper Falls.
G. A. Thudium	Supplies	Boston.
James P. Tolman	Samson Cordage Works	Boston.
Geo. W. Towne	Arlington Mills	Lawrence.
Oscar B. Truesdell	Fiskdale Mills	Fiskdale.
Jude C. Wadleigh	Mass. Cotton Mills	Lowell.
James Waring	Narragansett Mills	Fall River.
J. W. Wattles	Supplies	Canton.
George W. Weeks	Lancaster Mills	Clinton.
Channing Whitaker	Mill Engineer	Tyngsborough.
Arthur F. Whitin	Sanders C. Mills, Whitinsville C. Mills	Whitinsville.
G. Marston Whitin	Whitinsville Machine Works	Whitinsville.
Henry T. Whitin	Rockdale Mill	Northbridge.
Alfred N. Whiting	L. M. Harris Manufg. Co.	Oakdale.
William S. Whitney		Fall River.
Henry M. Wilcox	John Rhodes Warp Mill	Millbury.
Theoph. W. Wilmarth	Millbury Cotton Mill	Millbury.
Thomas Wilmarth	Saunders Cotton Mills	Saundersville.
C. J. H. Woodbury	Secretary and Treasurer	Lynn.
Erving Y. Woolley	152 Congress St.	Boston.

RHODE ISLAND.

Stephen L. Adams	Stafford Manufg. Co.	Central Falls.
Charles T. Aldrich	Aldrich Manufg. Co.	Providence.
William Ames	Fletcher Manufg. Co.	Providence.
Abel T. Atherton	A. T. Atherton Machine Co.	Pawtucket.
George R. Babbitt	American Oil Co.	Providence.
Truman Beckwith	Dyerville Manufg. Co.	Providence.
William W. Blades	Crefeld Mills	Westerly.
D. Russell Brown	Mill Supplies	Providence.
H. Martin Brown	Mill Supplies	Providence.
E. C. Bucklin	Interlaken Mills	Providence.
Malcolm Campbell	Woonsocket Machine & Press Co.	Woonsocket.
Arnold B. Chace, Jr.	Valley Falls Co.	Woonsocket.
Fred A. Chase	Mill Supplies	Providence.
Chas. H. Child	Brown Bros. Co.	Providence.
Frank B. Comins	Aerphor Co.	Providence.
Andrew J. Currier	Albion Mills	Albion.
Frederick I. Dana	Thomas Phillips Co.	Providence.
A. Lockwood Danielson	Quinebaug Co.	Providence.
J. DeForest Danielson	Lockwood Co.	Providence.

John W. Danielson	Quinebaug Co.	Providence.
R. H. Deming	Cotton	Providence.
William P. Dempsey	Dempsey Bleachery	Pawtucket.
Wm. H. Dyer	Reeds	Providence.
Herbert R. Farnum	Bernon Manufg. Co.	Georgiaville.
J. Herbert Foster	Cotton	Providence.
Geo. A. Fuller	Stedman & Fuller Manufg. Co.	Providence.
William Gammell	Berkeley Co.	Providence.
Charles H. Gorton	Ballou Mill	Woonsocket.
William B. Gowdey	Mill Supplies	Providence.
W. S. Granger	Granger Foundry & Machine Co.	Providence.
George P. Grant	Greene & Daniels Manufg Co.	Pawtucket.
R. A. Gray	Rodman Manufg. Co.	Allenton.
William C. Greene	Peacedale Manufg. Co.	Peacedale.
Frederick Grinnell	General Fire Extinguisher Co.	Providence.
Arthur H. Gulliver	Lonsdale Co.	Ashton.
Walter S. Hackney	Gen. Fire Extinguisher Co.	Providence.
John H. Hambly	Quidnick Manufg. Co.	Providence.
Frank Harris	Hamlet Mills	Woonsocket.
Alfred Hawkesworth	B. B. & R. Knight's Mill	Pontiac.
William P. Holt	Slatersville Mills	Slatersville.
Elisha H. Howard	Harris Manufg. Co.	Providence.
David Jackson	Cotton Machinery	Pawtucket.
J. E. Jenckes	E. Jenckes Co.	Pawtucket.
W. E. Keach	57 Harrison St.	Pawtucket.
Joseph H. Kendrick	American Supply Co.	Providence.
John M. Kimball	Slatersville Mills	Slatersville.
Albert Knight	Quidnick Manufg. Co.	Anthony.
Jessie A. Knight	W. H. Pope's Cotton Mill	Enfield.
Stephen A. Knight	Hebron Manufg. Co.	Providence.
Walter B. Knight	Reynolds Manufg. Co.	Davisville.
Harold Lawton		Centreville.
J. Colby Lewis	Centreville Cotton Mill	Centreville.
Charles W. Lippitt	Social Manufg. Co.	Providence.
Henry F. Lippitt	Globe Mill	Providence.
Jas. R. MacColl	Lorraine Manufg. Co.	Pawtucket.
Charles R. Makepeace	Mill Engineer	Providence.
Arthur B. Mann	U. S. Cotton Co.	Central Falls.
F. H. Maynard	General Fire Extinguisher Co.	Providence.
Thomas Mayor	Textile Machinery	Providence.
Charles H. Merriman, Jr.	Social Co.	Woonsocket.
O. B. Parker	U. S. Cotton Co.	Central Falls.
Geo. C. Phillips	Tape Dressers	Providence.
Wm. C. Pierce	Elizabeth Mills	Providence.
Stephen Minot Pitman	Narragansett Fire Insurance Co.	Providence.
Thomas C. Powell	Slatersville Mills	Providence.

R. H. Rice	Rice & Sargent Steam Engine Co.	Providence.
Charles D. Robinson	Crompton Co.	Crompton.
Charles H. Savage	Manville Co.	Manville.
Arnold Schaer	Warren Manufg. Co.	Warren.
Frank P. Sheldon	Mill Engineer	Providence.
George E. Sherman		Valley Falls.
Herbert H. Shumway	Mills of B. B. & R. Knight	Providence.
George W. Stafford	Knowles Loom Works	Providence.
Daniel J. Sully	Cotton Broker	Providence.
Edward P. Taft	Ponemah Mills	Provideuce.
Robert W. Taft	Coventry Co.	Providence.
Ariel C. Thomas	Clinton Manufg. Co.	Woonsocket.
Charles E. Thomas	Forestdale Manufg. Co.	Woonsocket.
D. M. Thompson	Corliss Steam Engine Co.	Providence.
Robert B. Treat	Centreville Cotton Mills	Centreville.
John Waterman	Warren Manufg. Co.	Warren.
A. Tenny White	Globe Mill	Woonsocket.
A. S. Winslow	Crompton Co.	Crompton.

CONNECTICUT.

Joseph D. Aiken	Ponemah Mills	Taftville.
H. C. Atwood	Williamsville Manufg, Co.	Killingly.
James A. Atwood	Wauregan Manufg. Co.	Wauregan.
W. E. Atwood	Williamsville Manufg. Co.	Killingly.
George S. Barnum	Bigelow Co.	New Haven.
E. S. Boss	Willimantic Linen Co.	Willimantic.
Walter D. Brigham	Willimantic Linen Co.	Willimantic.
W. R. Burnham	Uncasville Manufg. Co.	Norwich.
Chauncey C. Chase	Attawaugan Mills	Killingly.
John Eccles	Ponemah Mills	Taftville.
C. H. Frisbie	Attawaugan Mills	Norwich.
George W. Holt	Monohansett Manufg. Co.	Putnam.
William C. Jillson	Hop River Manufg. Co.	Willimantic.
Ira J. Martin	Bozrahville Manufg. Co.	Bozrahville.
Frank M. Messenger	Grosvenor Dale Co.	No. Grosvenor Dale.
Moses Pierce	Norwich Bleachery	Norwich.
John Scott	Willimantic Linen Co.	Willimantic.
Robert R. Smith	Greenwoods Co.	New Hartford.
James O. Sweet	Ashland Cotton Co.	Jewett City.
Robert Rennie Taft	Baltic Mills	Baltic.
E. B. Wilbur	Pequot Mills	Montville.
Alvin Woodman	Jewett City Mills	Jewett City.
A. A. Young, Jr.	Jewett City Mills	Jewett City.
Adelbert R. Young	Ashland Cotton Co.	Jewett City.

NEW YORK.

HONORARY MEMBER.

George Arms . . . . . New York City.

ACTIVE MEMBERS.

Edwin H. Baker	Bliss, Fabyan & Co.	New York City.
D. W. Gray	Skenandoa Cotton Co.	Utica.
J. O. Hannum	Saratoga Victory Manufg. Co.	Victory Mills.
David S. Johnston	Cohoes Fdy. & Machine Co.	Cohoes.
William L. Lyall	J. & W. Lyall	New York City.
Henry F. Mansfield	Mohawk Valley Mills	Utica.
J. E. Prest	Harmony Mills	Cohoes.
G. H. Sayward	Standard Yarn Co.	Oswego.

NEW JERSEY.

Ernest Bridge	Jas. Chadwick & Bro., Ltd.	Jersey City.
J. William Clark	Clark Thread Co.	Newark.
John W. Fergurson	Mill Engineer	Paterson.
Philip H. Fowler	Gloucester Gingham Mills	Gloucester.
John K. Russell	May's Landing Water Power Co.	Vineland.
H. E. Walmesley	Clark Thread Co.	Newark.
William Whittam, Jr.	Jas. Chadwick & Bro., Ltd.	Jersey City.

PENNSYLVANIA.

James Butterworth	H. W. Butterworth & Sons	Philadelphia.
Richard Garsed	Wingohocking Mills	Philadelphia.
William E. McGill		Philadelphia.
S. S. Spencer	Conestoga Steam Mills	Lancaster.
William E. Trainer	Linwood Mills	Trainer.
George Wood	Millville Manufg. Co.	Philadelphia.

DELAWARE.

William P. Bancroft	Jas. Bancroft & Sons Co.	Wilmington.

MARYLAND.

James A. Gary	Alberton Cotton Mills	Baltimore.

VIRGINIA.

Osmon B. Tilton	Lynchburg Cotton Mills	Lynchburg.

KENTUCKY.

John Hopkinson		Stamford.
W. H. Summersby	Henderson Cotton Mills	Henderson.

GEORGIA.

Arthur W. Hunking	Mass. Mills in Georgia	Rome.
Albert G. Martin	Kincaid Manufg Co.	Griffin.
George R. Stearns	Riverside Mills	Augusta.

NORTH CAROLINA.

H. S. Chadwick	Dover Yarn Mills	Charlotte.

SOUTH CAROLINA.

B. F. Guy	Pelzer Manufg. Co.	Pelzer.
Horace L. Hayden	Walhalla Cotton Mills	Walhalla.
Charles K. Oliver	Columbia Mills Co.	Columbia.
Ellison A. Smyth	Pelzer Manufg. Co.	Greenville.
W. B. Smith Whaley	Richland Cotton Mills	Columbia.
H. D. Wheat	Gaffney Manufg. Co.	Gaffney.

LOUISIANA.

S. Odenheimer	Lane Mills	New Orleans.

TEXAS.

D. M. Ehrlich	Galveston C. & W. Mills	Galveston.
Lawrence V. Elder	Galveston C. and W. Mills	Galveston.

CANADA.

Chas. Owen Dexter	Canadian Colored Cotton Mills, Ltd.,	Hamilton, Ont.
F. J. Muir	Canadian Col. Cotton Co.	Hamilton, Ont.
Louis P. Simpson	Montreal Cotton Co.	Valleyfield, P. Q.

NEW BRUNSWICK.

John H. Parks	New Brunswick Cotton Mills	St. John.

ENGLAND.

George Ashworth	Manchester.

CHINA.

A. W. Danforth	Shanghai Cotton Cloth Mill Co.	Shanghai.

RECAPITULATION.

LOCATION OF MEMBERSHIP.

Maine	20
New Hampshire	23
Vermont	1
Massachusetts	183
Rhode Island	83
Connecticut	24
New York	9
New Jersey	7
Pennsylvania	6
Delaware	1
Maryland	1
Virginia	1
Kentucky	2
Georgia	3
North Carolina	1
South Carolina	6
Louisiana	1
Texas	2
Canada	3
New Brunswick	1
England	1
China	1
	380

IN MEMORIAM.

TIMOTHY MERRICK.

TIMOTHY MERRICK, of Holyoke, was the founder and the treasurer of the Merrick Thread Company, and had taken an original and independent stand in the manufacture of spool thread, in which he achieved a great success. He was also largely interested in the paper and wood pulp business, and also in railroad management.

He was born in Willington, Connecticut, in 1823, and died March 19, 1894. His seventy years of life were actively devoted to business ever since the age of eleven, when he entered a mill, and became thoroughly master of the cotton business.

He was a thorough mechanic in a wide range of construction, a practical financier, and endowed in a remarkable degree with a capacity for business organization, both in the initial steps of an enterprise and also in the administration of a business fully established. A man of affairs, always a leader in any enterprise which secured his affiliation. He was one of the founders of the Home Market Club and for several years its president. He was liberal in private charities, and was a member of the Baptist church. He possessed to a just degree the confidence of the community and of his business associates for his integrity and sound judgment.

HENRY SALTONSTALL.

HENRY SALTONSTALL, late Treasurer of the Pacific Mills, died at Boston, December 3, 1894. He was born at Salem, Mass., in 1823, and graduated at Harvard University in the class of 1848.

He was treasurer of several cotton mills, at various times. His latest position, that in connection with the Pacific Mills, began in 1880. He made in it a brilliant record in the manner in which he took executive charge of this great establishment, improving its character and enlarging the diversified scope of its product in a way which gave excellent commercial results. He was much interested in the Massachusetts Institute of Technology and the Massachusetts Agricultural Society, in both of which he held prominent offices, and although not officially connected with Harvard College, left it handsome sums for various purposes.

WILLIAM P. WARREN.

WILLIAM P. WARREN, of Westfield, Mass., was born at Portland, Maine, September 2, 1855, and died after a short sickness of the grippe, January 16, 1895. During his relatively short life he had shown a great business ability as manager of the W. Warren Thread Works, and also in his connection with the Foster Machine Company and the Westfield Creel Company. He was a man of great business energy and yet conducted in the most conservative manner the establishments intrusted to him. In his personal presence he was very genial and had a kindly manner which endeared him to all with whom he came in contact; and this in combination with a keen discernment of human nature enabled him to secure the affiliation of able men in his extensive affairs.

ECKLEY B. COXE.

Although not a member of the New England Cotton Manufacturers' Association, Mr. COXE was greatly interested in the progress of textile industries in this country, and in the establishment of which his grandfather bore an active part.

He expressed himself highly gratified at receiving an invitation to address the Providence meeting of the Association, and the result of his efforts is contained in this volume of the Transactions.

His sudden death interfered, no doubt, with other plans which he had in mind which would bring him into closer relationship with this organization.

He was born in Philadelphia, June 4, 1839, and died at his home in Drifton, Penn., on May 13, 1895, at the age of fifty-six.

He was a graduate of the University of Pennsylvania, at Philadelphia, and also at the School of Mines in Paris, and the School of Mines in Fryeburg in Saxony. He had also spent a great deal of time in the study of coal mining throughout the world.

He was a peculiar combination of the brilliant scholar and the successful business man, administering his large affairs in the mining of coal, railroad transportation and other corporations in a most successful manner, which rendered him at his decease one of the most wealthy men in Pennsylvania.

As a scholar in technical lines of learning, he sustained a similar prominence. His full colloquial mastery of French and German enabled him to avail himself of the volumes of technical investigation published in these languages.

His library was contained in a large brick building, specially built for the purpose, under the care of a librarian, and was probably the best engineering library in this country.

He has been a writer upon engineering subjects, being known most widely in connection with his translation of Weisbach's "Mechanics of Engineering," and he has also written several

papers upon matters pertaining to mining, engineering, and metallurgy, of which the one presented before this Association may justly be considered as an honorable climax to a brilliant life.

He was a member of each of the three engineering societies of America, and has been president of the American Institute of Mining Engineers, and also of the American Society of Mechanical Engineers.

His life showed that a geniality of disposition and philanthropic action were not inconsistent with the career of a forceful man of affairs.

CALL FOR MEETING.

NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION,
Providence Meeting, No. 58,
BOSTON, MASS., April 3, 1895.

Dear Sir:

The stated annual meeting of the Association will be held at Providence, Rhode Island, on Wednesday and Thursday, April 24, 25, 1895, in acceptance of an invitation extended by Rhode Island members of the Association, and by authority of special Act of the Legislature of Massachusetts [Chap. 163, Acts of 1895]. The sessions will be held in Savoy Hall, on Matthewson street, whose location is marked on the annexed plan of that portion of the city, Matthewson street crossing Westminster street at Grace Church, a few minutes' walk south of the City Hall.

The headquarters of the Association will be at the Narragansett Hotel, which has made special rates from $3.00 per day upwards, to members of the Association. Other hotels are the City Hotel at $2.00 per day, the Perrin House, $2.00 per day, Hotel Dorrance, on the European plan. Rooms can also be furnished at the Providence Athletic Association to those who have a letter of introduction to that club from one of its members. Members engaging rooms in advance will please correspond directly with the hotel.

The general arrangements of the meeting are in the hands of a local committee, consisting of Messrs. D. M. THOMPSON, *Chairman*, STEPHEN A. KNIGHT, and JOHN W. DANIELSON. This committee has appointed Mr. DANIEL J. SULLY as the local Secretary.

The sessions will be held mornings at ten and evenings at eight at Savoy Hall, and afternoons will be given up to acceptance of hospitalities which have been extended. On Wednesday afternoon at two o'clock, special electric cars will leave the corner of Weybosset and Dorrance streets, next to the Narragansett Hotel, to convey the party to the works of the Gorham Manufacturing Company, who have invited the Association to visit its establishment. At four P. M., the party will take the electric cars again and be conveyed to the works of the Corliss Steam Engine Company, and visit the establishment, in acceptance of the invitation tendered by D. M. THOMPSON, Esq., President. On Thursday afternoon there will be a Rhode Island shore dinner at the Pomham Club, tendered by His Excellency Hon. D. Russell Brown, Governor of Rhode Island, and others. Special electric cars will leave from the front of Savoy Hall at 1 o'clock P. M., and dinner will be served at 2 P. M. The entainments will be restricted to members of the Association and invited guests, including ladies, and candidates for membership, who are welcomed upon all occasions. Invitations will be necessary for the dinner, and can be obtained on Wednesday by those entitled to them, from Mr. DANIEL J. SULLY, the local Secretary.

In addition to the annual business meeting of the Association, papers on the following subjects will be presented:

1. Topical questions, contained on the accompanying sheet will be presented in order at various sessions.

2. Opening Address.

Mr. D. M. THOMPSON, Providence. R. I.

3. Vertical Engines for Cotton Mills.

Mr. RICHARD H. RICE, Providence, R. I.

4. The Ideal Cotton Mill Steam Plant, its Design and Management.

Mr. GEORGE C. ROCKWOOD, Worcester, Mass.

5. The Steam Creed.

Capt. CHAS. H. MANNING, U. S. N., Manchester, N. H.

6. Some Thoughts on the Production of Steam, with Special Reference to the Use of Cheap Fuel.
By a Miner of Coal, Mr. ECKLEY B. COXE, Drifton, Penn.

7. Water Power, its Development.
Col. SAMUEL WEBBER, Charlestown, N. H.

8. Water Power Development and its Cost.
Mr. A. C. RICE, Dayton, O.

9. Electrical Driving of Textile Establishments.
Mr. SIDNEY B. PAINE, Boston, Mass.

10. Operating by Electricity from a Distance.
Mr. JOHN ECCLES, Taftville, Conn.

11. Generation and Distribution of Electric Power for Manufacturing Purposes.
Messrs. C. A. STONE and E. S. WEBSTER, Boston, Mass.

12. Equitable Payment of Prices for Weaving Various Styles of Goods.
Report of Committee: { Mr. E. W. THOMAS, Lowell, Mass. / Mr. A. F. KNIGHT, Manchester, N. H.

13. Humidifying and Ventilating Mills.
Mr. OTTO HOFFMAN, Manchester, England.

14. The Principles of Construction of Card Clothing.
Mr. JOSEPH NASMITH, Manchester, England.

Blank proposals for membership can be obtained at the rooms of the Association or from the Secretary, P. O. Box 3672, Boston, Mass., and it is important that nominations for membership be in his hands not later than April 22.

In answer to numerous enquiries on the subject of back numbers of the Transactions, it may be stated that the files of the Association were destroyed by fire in 1890, and there is a limited supply of copies, beginning with the report of the meeting of April, 1890, the price of which as fixed by the Board of Government, is fifty cents to members, and five dollars to non-members.

The headquarters of the Board of Government, room 501

John Hancock Building, 178 Devonshire street, and 35 Federal street, are open during business hours, and a stenographer is in attendance who will attend to any correspondence or typewriting for the members. The leading textile and mechanical papers are on file, and a beginning has been made on a library of textiles, for which further contributions are respectfully solicited.

By order of the Board of Government,

C. J. H. WOODBURY,

Secretary.

FIG. 1.

NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION.

TOPICAL QUESTIONS.

PROVIDENCE MEETING, NO. 58, SAVOY HALL, PROVIDENCE, R. I.

April 24, 25, 1895.

Dear Sir:

These topical questions upon the live issues of cotton manufacturing, suggested by various members, are presented with the approval of the Board of Government for discussion, with remarks not exceeding five minutes by any speaker.

It is expected that the members will show their approval of this new feature and warrant its continuance by promptly entering upon the discussions and submitting facts and opinions bearing directly upon the questions, thus giving the Association benefits derived from practical experience and observation.

Members notifying the Secretary in advance of their willingness to speak upon the topical questions will be given precedence by the President.

Suggestions for other questions, to be discussed at future meetings, may be given to the Secretary.

By order of the Board of Government,

C. J. H. WOODBURY,

P. O. Box 3672, BOSTON,

Secretary.

26. English practice has been in the direction of separating the business of spinning from that of weaving. What are the advantages of this separation? Is there any such tendency discernible in American practice at the present time?

27. With conditions and appliances favorable to the maintenance of uniform steam pressure at the cylinder, how close ought a first-class steam engine to keep to standard speed in driving a cotton mill?

28. The English time table for 56½ hours per week divides the working day into three parts, with an hour for breakfast and an hour for dinner. What advantage has the plan over the American system?

29. How can the superintendent or manager of a mill best get at the sentiment of his employees upon matters of reform or wages?

30. Tare on cotton. Is it not excessive? Can agitation among manufacturers have any effect to reducing weight of hoops, sacking, etc.?

31. Is a scutcher in a finisher picker of as much benefit towards making good, strong yarn as a licker-in on a card?

32. What is the best method of ventilating rooms?

a. Carding.
b. Spinning.
c. Weaving.

33. What is the best method of sizing cotton warps?

34. What is the best method of lubricating shafting overhead, in weaving rooms, to prevent oil stains on cloth?

35. What is the best way of lubricating the necks of rolls to prevent oil-stained filling and warp yarns?

36. What is the best number of wire and number of points, per square foot, for cylinders, doffers and flats, for the plain top card?

a. On breaker carding?
b. On finisher carding?
c. On single carding?
d. Also on the cylinders, doffers and flats of revolving flat cards?

37. Would not a device, entirely separate from the governor, applied to steam engines or other motors to stop them when five to ten per cent. above speed prevent many fly-wheel accidents?

38. What is the comparative cost of arc and incandescent lighting?

39. What is the best arrangement by which a manager can communicate with any department as occasion may require?

The discussion of the Topical Questions stopped at number 39, and the consideration of the remainder will be taken up at the next meeting.

40. What is the best running time for our mills? Best time to start? Best time to stop? Best length of time for noon hour, etc.? Any good points in the English method? Is there anything to be gained to the mills and employees by a standard uniform system?

41. What type of boiler is most economical for high pressures, cost of installation, operation, and depreciation being considered?

42. Is the economy obtained with steam jacketed cylinders sufficient to warrant the extra cost and risk incurred by their use?

43. Is the cone warper an improvement? If so, in what respect?

44. Will a picker take out more dirt by introducing air in the end of the bonnet than it would to draw the air over the grid bars?

45. The new French beater, its work on ordinary cotton and long staples.

46. How can exhaust steam be best utilized in a cotton mill?

47. What is the best method of automatically stopping an engine in case the governor fails to operate?

48. Is there any practical difficulty in the way of regulations of engines and water-wheels when working together?

49. What have you learned from your experience with mill fires during the past year?

50. The relative importance of vapor, steam, the aerophor, and the Sturtevant blower system?

51. What principle of first picker or opener is best adapted for

a. Middling American Cotton.

b. Long staple peeler Egyptian and Sea Island Cotton.

c. What relation should the speed of the beaters in all packing room machinery have to the grade of stock being used?

52. If upright boilers are used, will the steam be made more cheaply by using all soft coal, or by mixing soft coal and buckwheat coal?

53. How much can be gained by using a forced draft, when the chimney draft is not enough to give thorough combustion?

54. What is the best method of returning condensed steam to the boilers?

55. Can oil in condensed steam be separated by any means so that the water can with safety be returned to the boiler?

PROCEEDINGS.

In accordance with the foregoing notice, the stated annual meeting of the Association was held at Savoy Hall, Providence, R. I., on April 24, 25, 1895. The following were present:

ALFRED E. ADAMS, Whitinsville.
STEPHEN L. ADAMS, Central Falls, R. I.
JOSEPH D. AIKEN, Taftville, Conn.
G. M. ANGIER, Boston, Mass.
WILLIAM AMES, Providence, R. I.
ABEL T. ATHERTON, Pawtucket, R. I.
H. C. ATWOOD, Killingly, Conn.
W. E. ATWOOD, Killingly, Conn.
GEORGE R. BABBITT, Providence, R. I.
CHARLES L. BAILEY, Waltham, Mass.
EDWARD R. BALLOU, New Bedford, Mass.
GEORGE S. BARNUM, New Haven, Conn.
EDWIN N. BARTLETT, North Oxford, Mass.
TRUMAN BECKWITH, Providence, R. I.
WILLIAM W. BLADES, Westerly, R. I.
N. B. BORDEN, Fall River, Mass.
RICHARD B. BORDEN, Fall River, Mass.
STEPHEN N. BOURNE, Manchester, N. H.
ERNEST BRIDGE, Jersey City, N. J.
H. MARTIN BROWN, Providence, R. I.
D. RUSSELL BROWN, Providence, R. I.
MALCOLM CAMPBELL, Woonsocket, R. I.
W. W. CAREY, Lowell, Mass.
ARNOLD B. CHACE, JR., Valley Falls, R. I.
GEORGE A. CHACE, Fall River, Mass.
CHAUNCEY C. CHASE, Killingly, Conn.
FRED A. CHASE, Providence, R. I.
CHARLES H. CHILDS, Providence, R. I.

JEREMIAH CLARK, Lowell, Mass.
FRANK B. COMINS, Providence, R. I.
J. J. CONNELL, Taunton, Mass.
PETER H. CORR, Taunton, Mass.
THOMAS G. COX, Taunton, Mass.
F. I. DANA, Providence, R. I.
WOODBURY K. DANA, Saccarappa, Me.
A. LOCKWOOD DANIELSON, Providence, R. I.
J. DEFOREST DANIELSON, Providence, R. I.
JOHN W. DANIELSON, Providence, R. I.
E. P. DENNIS, Lowell, Mass.
CHARLES A. DENNY, Leicester, Mass.
CHARLES C. DIMAN, New Bedford, Mass.
EBEN S. DRAPER, Hopedale, Mass.
GEORGE OTIS DRAPER, Hopedale, Mass.
GEORGE A. DRAPER, Hopedale, Mass.
WILLIAM F. DRAPER, JR., Hopedale, Mass.
C. E. W. DOW, Indian Orchard, Mass.
WM. H. DYER, Providence, R. I.
WILLIAM A. EASTMAN, Lowell, Mass.
RUSSELL W. EATON, Brunswick, Me.
JOHN ECCLES, Taftville, Conn.
FREDERICK W. ELY, Greenville, N. H.
T. C. ENTWISTLE, Lowell, Mass.
H. W. ESTES, Lewiston, Me.
HERBERT R. FARNUM, Georgiaville, R. I.
CLIFTON L. FIELD, Shattuckville, Mass.
WILLIAM FIRTH, Boston, Mass.
CHARLES H. FISH, Manchester, N. H.
HERBERT FISHER, Taunton, Mass.
WILLIAM B. FITTZ, Oakdale, Mass.
FREDERICK A. FLATHER, Lowell, Mass.
J. HERBERT FOSTER, Providence, R. I.
M. F. FOSTER, Milford, N. H.
C. H. FRISBIE, Norwich, Conn.
GEORGE A. FULLER, Providence, R. I.
WILLIAM GAMMELL, Providence, R. I.
ROYAL W. GATES, Lowell, Mass.
ALLAN V. GARRATT, Boston, Mass.
CHARLES GETCHELL, Bondsville, Mass.
ALFRED M. GOODALE, Boston, Mass.
WILLIAM B. GOWDEY, Providence, R. I.
W. S. GRANGER, Providence, R. I.
GEORGE P. GRANT, Pawtucket, R. I.

GEORGE P. GRANT, JR., Fitchburg.
D. W. GRAY, Utica, N. Y.
R. A. GRAY, Allenton, R. I.
STEPHEN GREENE, Boston, Mass.
JOHN GREGSON, Fall River, Mass.
ARTHUR H. GULLIVER, Ashton, R. I.
FRANK J. HALE, Newton Upper Falls, Mass.
SAMUEL HALE, So. Berwick, Me.
JOHN H. HAMBLY, Providence, R. I.
J. O. HANNUM, Victory Mills, N. Y.
FRANK HARRIS, Woonsocket, R. I.
HENRY F. HARRIS, Worcester, Mass.
FRANK HASKELL, Saccarappa, Me.
WM. B. HAWES, Fall River, Mass.
JOHN H. HINES, Burlington, Vt.
CHARLES H. HOBBS, Thorndike, Mass.
WILLIAM P. HOLT, Slatersville, R. I.
GEORGE L. HOOPER, Lowell, Mass.
HENRY S. HOUGHTON, JR., Whitinsville.
WM. B. KEHEW, Boston, Mass.
ROLAND R. KELLY, Williamstown, Mass.
JOSEPH H. KENDRICK, Providence, R. I.
WILLIAM J. KENT, New Bedford, Mass.
JOHN KILBURN, Belmont, Mass.
JOHN M. KIMBALL, Slatersville, R. I.
ALBERT KNIGHT, Anthony, R. I.
ALBERT F. KNIGHT, Manchester, N. H.
JESSE A. KNIGHT, Enfield, R. I.
STEPHEN A. KNIGHT, Providence, R. I.
WALTER B. KNIGHT, Davisville, R. I.
ABBOTT F. LAWRENCE, Taunton, Mass.
HAROLD LAWTON, Centerville, R. I.
EVAN ARTHUR LEIGH, Boston, Mass.
J. COLBY LEWIS, Centerville, R. I.
ARTHUR H. LOWE, Fitchburg, Mass.
DAVID LOWE, Fitchburg, Mass.
WILLIAM L. LYALL, New York.
JAMES R. MACCOLL, Pawtucket, R. I.
CHARLES L. MACOMBER, Taunton.
CHARLES T. MAIN, Boston, Mass.
CHARLES R. MAKEPEACE, Providence, R. I.
ARTHUR B. MANN, Central Falls, R. I.
CHARLES H. MANNING, Manchester, N. H.
HENRY F. MANSFIELD, Utica, N. Y.

IRA J. MARTIN, Bozrahville, Conn.
F. H. MAYNARD, Providence, R. I.
THOMAS MAYOR, Providence, R. I.
CHARLES D. MCDUFFIE, Manchester, N. H.
FRED C. MCDUFFIE, Boston, Mass.
JOHN TEMPEST MEATS, Taunton, Mass.
FRANK M. MESSENGER, No. Grosvenordale, Conn.
A. B. MOLE, Adams, Mass.
EDWARD A. MONGEON, Blackstone.
FRED MOORE, Millbury, Mass.
ALBERT MORTON, Lowell, Mass.
OSCAR L. OWEN, Whitinsville, Mass.
O. B. PARKER, Central Falls, R. I.
ELMER E. PAGE, Saco, Me.
WALTER E. PARKER, Lawrence, Mass.
HAVEN C. PERHAM, Lowell, Mass.
GEORGE C. PHILLIPS, Providence, R. I.
WM. C. PIERCE, Providence, R. I.
THOMAS C. POWELL, Providence, R. I.
HERBERT L. PRATT, Lewiston, Me.
ROBERT REDFORD, Lawrence, Mass.
ROSCOE C. REYNOLDS, Lewiston, Me.
CHARLES D. ROBINSON, Crompton, R. I.
JOHN K. RUSSELL, Vineland, N. J.
ARNOLD SCHAER, Warren, R. I.
FRANK P. SHELDON, Providence, R. I.
GEORGE E. SHERMAN, Valley Falls, R. I.
WILLIAM F. SHERMAN, Lawrence, Mass.
HERBERT H. SHUMWAY, Providence, R. I.
ARBA C. SLATER, Whitinsville, Mass.
ROBERT R. SMITH, New Hartford, Conn.
S. S. SPENCER, Lancaster, Penn.
GEORGE W. STAFFORD, Providence, R. I.
W. H. SUMMERSBY, Pontiac, R. I.
JAMES O. SWEET, Jewett City, Conn.
CYRUS A. TAFT, Whitinsville, Mass.
EDWARD P. TAFT, Providence, R. I.
ROBERT W. TAFT, Providence, R. I.
JAMES W. TAYLOR, Taunton, Mass.
EARL A. THISSELL, Florence, Mass.
EDWARD W. THOMAS, Lowell, Mass.
RALPH E. THOMPSON, Fitchburg, Mass.
D. M. THOMPSON, Providence, R. I.
G. A. THUDIUM, Boston, Mass.

WM. V. THRELFALL, Newton Upper Falls, Mass.
JAMES P. TOLMAN, Boston, Mass.
ROBERT B. TREAT, Centerville, R. I.
JUDE C. WADLEIGH, Lowell, Mass.
H. E. WALMESLEY, Newark, N. J.
JAMES A. WALSH, Lewiston, Me.
JAMES WARING, Fall River, Mass.
JOHN WATERMAN, Warren, R. I.
J. W. WATTLES, Canton, Mass.
T. B. WATTLES, Penacook, N. H.
GEORGE W. WEEKS, Clinton, Mass.
W. B. SMITH WHALEY, Columbia, S. C.
A. TENNY WHITE, Woonsocket, R. I.
G. MARSTON WHITIN, Whitinsville, Mass.
HENRY T. WHITIN, Northbridge, Mass.
ALFRED N. WHITING, Oakdale, Mass.
WILLIAM WHITTAM, JR., Jersey City, N. J.
E. B. WILBUR, Montville, Conn.
HENRY W. WILCOX, Milbury, Mass.
THEOP. W. WILMARTH, Milbury, Mass.
THOMAS WILMARTH, Saundersville, Me.
A. S. WINSLOW, Crompton, R. I.
C. J. H. WOODBURY, Lynn, Mass.
E. Y. WOOLLEY, Boston, Mass.

MORNING SESSION, APRIL 24, 1895.

The session was called to order at 10 A. M. by the President, Mr. EDWARD W. THOMAS, and the Secretary read the call for meeting.

The SECRETARY. Mr. President, I certify that I have mailed the call to the meeting at least ten days in advance of the present date, in accordance with Article 14 of the Constitution, to every member of the Association.

The Secretary then read the following act of the Legislature of the Commonwealth of Massachusetts (Chap. 163, Acts of 1895):

AN ACT TO AUTHORIZE THE NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION TO HOLD ITS MEETINGS WITHOUT THE COMMONWEALTH.

Be it enacted as follows:

SECTION 1. The New England Cotton Manufacturers' Association is hereby authorized to hold its meetings in any state or territory of the United States and in the District of Columbia: provided, however, that its annual meeting shall be held in this Commonwealth at least once in five years.

SECTION 2. This act shall take effect upon its passage.—*Approved March 23, 1895.*

The SECRETARY. I declare that a quorum is present.

The Secretary then read the records of the last meeting.

On motion, duly seconded, it was voted that the report of the Secretary be accepted.

PRESIDENT'S ADDRESS.

To the Members of the New England Cotton Manufacturers' Association,

Gentlemen:—It is exceedingly gratifying to the Board of Government of this Association to observe the large attendance at this first session of our fifty-eighth meeting. We hope and expect that the innovation incorporated at our last meeting of holding our meetings outside the city of Boston, will prove a success. So far we have every indication that the present meeting will be one of the best attended and of more practical benefit to the members than any previous ones.

And to the local committee of arrangements I desire, in behalf of the Association, to extend our sincere thanks for the most excellent arrangements they have made for our comfort and entertainment; and let us, as members, show our appreciation by making this meeting an historic one both in attendance and in the quality of the subjects to be introduced for discussion.

To the many who have recently become members of this Association the following may be of interest.

In the early part of 1865 considerable interest was manifested by a number of manufacturers, toward the formation of an association whose members were to be composed of the various New England agents and managers of cotton mills.

At a meeting held July 26, 1865, such an organization was formed, and our records show its first list of officers as follows:

President, HON. E. A. STRAW.
Vice-Presidents, A. D. LOCKWOOD and WM. A. BURKE.
Board of Government, J. S. DAVIS, CHAS. NOURSE, PHINEHAS ADAMS, WM. P. HAINES, T. J. BORDEN and D. D. CROMBIE.

It will be observed that but one of the foregoing is to-day a member, the others having passed beyond.

The roster of the members of the Association for the year 1866 shows seventy-one names; of this number but twelve are members at present.

The original Preamble and By-Laws as adopted contain in a few words the motives and objects of the few who formed its organization. It says:

"The undersigned, Agents and Managers of Cotton Mills in New England, desirous of promoting a more intimate acquaintance with each other, and of collecting and imparting information as to the best methods of manufacturing Cotton, hereby form ourselves into an Association," etc.

It is quite refreshing to look back thirty years ago and find that these pioneers of manufacturing were not too conservative and were willing to meet for the purpose of relating the experiences and furnishing statistics for the benefit of themselves and each other. I have been very much impressed with the first paper ever presented to the Association, prepared by Mr. FRANKLIN FORBES, of Clinton, Mass., in the conclusion of which he said: "It (the paper) was prepared in the expectation that it would inaugurate a full discussion of many points, in order that the varying views and opinions of experienced members might be drawn out and thus valuable hints and knowledge be brought out."

The lesson to be drawn from his remarks for your reflection is, that we should all interest ourselves in a full and free discussion of any and all the papers and topical questions presented, and make our present meeting one of great profit and experience. The cotton manufacturing industry is one having a wide field, and our methods and systems have by no means reached the point of perfection.

The history of the Association is a very instructive one, and after its thirty years of life it has grown to full manhood, and to-day is just entering the arena of progression and enterprise. It ought to-day, and I predict it will, emulate in a large degree the example of our somewhat kindred societies that have grown to an extremely healthy existence long after our first formation.

As I remarked before, we have before us a wide field for investigation and experiment. We must be keenly alive to the

future and its great possibilities, and use any and all legitimate methods of obtaining information for the working of cotton into yarns and cloth in the simplest and most profitable manner. We have but to look about us and note the great improvements in the manufacture of iron, steel, and many other of the great industries of the country. And it sometimes seems as though cotton manufacturing, with its 18,000,000 spindles and its $300,000,000 capital invested, in this country alone, should in the last quarter century have been much farther advanced in its simplicity and improved machinery than it has. However, our progression may have been as rapid as was natural and judicious. It is a matter of pride that much of the development of manufacturing and machinery since the formation of this Association, has been by and through those who were and are its members. Among others, I must refer briefly to Messrs. DRAPER, LOCKWOOD, SAWYER and BURKE, to whom we owe much.

Membership. It has been deemed advisable in consideration of the fact that our doors are now open as associate members, to those who are not actively engaged in cotton manufacturing, that we do not allow any others than members or associate members to attend our sessions. Heretofore there have been no restrictions as to allowing outsiders to attend the meetings. It has in a measure been criticised by members in the past, who claim that outsiders were getting as much benefit as they without paying for it. The recent enactment allowing others than those actively engaged in cotton manufacturing, to become associated with us as associate members is to be strongly commended, and its first fruits are manifested to-day when there will be presented some names of such for your action.

Board of Government. I desire to say a few words upon the labor performed by the Board of Government since our last meeting. The question first before the Board was as to where the next meeting should be held. The matter of holding our last fall meeting at the mountains was an experiment, and one

which proved a highly successful one, and encouraged by this, your Board deemed it wise to accept the suggestion of some of our Providence friends that this the annual meeting be held in that city. This was decided upon, a local committee of arrangements appointed, and I feel it safe to say at this early stage of your proceedings, that none will be disappointed; and that the city of Providence will have the distinction of being the first city outside Massachusetts to hold the annual meeting of the Association.

Since our last meeting the Association has been incorporated under the Statute Laws of Massachusetts, and are allowed to hold their meetings in any state or territory, excepting once in five years, when it must be held in Massachusetts. The bill as presented was accepted and reported on favorably by the Committee on Mercantile Affairs, and eventually passed both branches and was signed by the Governor.

The Board has been in session several times since the last meeting, and with the assistance of our very efficient Secretary, has arranged for your entertainment at the present session.

Headquarters have been engaged at John Hancock Building, Boston, and you will find there all the latest issues of the trade and textile papers and magazines, and conveniences for correspondence. The room is open throughout the day and is attended by Mr. A. C. SLEEPER, an experienced stenographer and typewriter.

It is the intention of the Board to incorporate a library of the best and latest works on textiles, and any contributions to this end from any member will be fully appreciated. We desire you all to feel at liberty in the use of this room for such purposes as have been mentioned, as well as for making any business engagements with any party. A long distance telephone has been placed in the room.

The Board of Government holds its sessions on the last Wednesday of every month throughout the year, and they cordially welcome at these meetings any communications from the

members making suggestions for subjects for papers to be read or questions for discussion to be brought up at the annual or semi-annual meetings.

For many years it has been the custom at our annual meetings, held in April, to elect the President for the coming year, and have him take his office immediately after such election, generally at the opening of the session. Your Board of Government have decided to adopt the idea, and I trust with your cordial approval, of having the present President hold office until the close of the annual meeting. For many obvious reasons this is reasonable. From a personal experience in assuming the office a year ago and presiding at the meeting, the details of which had all been prepared mainly by the retiring President, rendered it a very trying position to fill at the time. Our object is this, that the President and the Board of Government who have been for six months preparing the details, etc., for the annual meeting, should continue as officials throughout that meeting, and that the term of office of the incoming Board and President commence at the close of each annual meeting.

At no time in the history of the Association has there been so full an attendance of the members of the Board of Government at its meetings as during the past year, and I desire as President of the Association to extend to them and to the members of the Association my heartfelt thanks for the many kindnesses and favors granted during my term.

In connection with the election of officers for the ensuing year, it is proposed to appoint a nominating committee this morning, who are to report the ticket at the opening of the session on Thursday morning. The committee thus having practically twenty-four hours in which to perform their duty. Printed ballots will be provided for the use of members in voting. The officers to be nominated by the committee are, a President, two Vice-Presidents, and two members for Board of Government to serve three years, and one member to serve one year.

The PRESIDENT. The next thing is the Treasurer's Report.

TREASURER'S REPORT.

C. J. H. WOODBURY, TREASURER, IN ACCOUNT WITH THE NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION.

September 10, 1894 to April 1, 1895.

Dr.

Interest on bank account,	$4 04	
Rent of desk room,	8 33	
Sale of transactions,	27 50	
Cash received from Ambrose Eastman, treasurer,	74 86	
Admission fees,	240 00	
Membership dues,	1,395 00	
Total,		$1,749 73

Cr.

Copyright Volume 57, Transactions,	$1 00	
By-laws and distribution,	12 15	
Stationery and record books,	17 75	
Engraving in Volume 57, Transactions,	19 73	
Committee on analysis of size,	30 00	
Notices to members,	46 75	
Incorporation,	55 00	
Meetings,	60 08	
Rent of office,	66 89	
Stenographer,	68 35	
Postage, express and telegraph,	70 66	
Office furniture,	70 43	
Reporting White Mountain meeting,	94 00	
Board of Government,	107 05	
Secretary and Treasurer,	108 33	
Transactions, Vol. 57, and distribution,	342 83	
Cash on hand,	578 73	
Total,		$1,749 73

I hereby certify that the accounts from September 5, 1894, to April

1, 1895, are correctly cast, that all payments are properly vouched by bills approved by the Auditing Committee of the Board of Government, that the funds are kept on deposit in the name of the New England Cotton Manufacturers' Association, and that the amount of deposit April 1st, agrees with the balance on the books, $578.73.

J. H. SAWYER, *Auditor.*

Boston, April 20, 1895.

Upon motion, duly seconded, it was voted that the Treasurer's Report be accepted.

The PRESIDENT. The first business before the meeting is to take any action on the filling of the vacancy caused by the expiration of the term of the President, Vice-President, and two members of the Board of Government.

On motion, duly seconded, it was voted that a committee, consisting of five members, be appointed by the Chair to nominate officers for the ensuing year. The committee consisted of the following gentlemen: Messrs. RUSSELL W. EATON, STEPHEN A. KNIGHT, JOHN M. KIMBALL, HAVEN C. PERHAM, M. F. FOSTER.

The SECRETARY. I am requested to give notice that the Committee on Nominations will meet directly after the morning session, and it is expected that their report will be furnished to the Association in season for balloting to-morrow morning.

I am requested to give notice on behalf of the Local Committee that the time of starting of the special electric cars for this Association this afternoon and to-morrow afternoon will be in accordance with the schedule, which must be kept on account of the other occupants of the track as exactly as if it were a train of steam cars that we were to take.

In regard to the dinner to-morrow afternoon, tickets may be obtained through the courtesy of GOVERNOR BROWN and some of his associates, of the local members, from Mr. DANIEL J. SULLY, the Secretary of the Local Committee, and it is expected that these tickets will be taken to-day, in order that the arrange-

ments may be made in season. It is a very large party, and unusual arrangements will be made for the Rhode Island Clambake.

A recess of five minutes was taken to allow the distribution of the badges for the meeting.

The PRESIDENT. I take pleasure in introducing to you this morning HIS EXCELLENCY D. RUSSELL BROWN, Governor of Rhode Island.

GOVERNOR BROWN. *Mr. President and members of the New England Cotton Manufacturers' Association:* It is my pleasant privilege to extend to you this morning in the name of the Rhode Island members of our Association, a hearty welcome to this State.

I welcome you in a two-fold capacity. First as representative of a State whose history is so closely identified with the birth and development of cotton manufacturing and whose industrial prominence to-day is due to its progress in textile industries. And then again I extend the hand of good fellowship as one of yourselves, who though not directly engaged in spinning and weaving, is perhaps just as much interested in the protection, progress and promotion of this important national industry.

Our State, I think you will all agree, has been faithful to the heritage of that pioneer manufacturer, SAMUEL SLATER, who a century and more ago, chose Rhode Island soil wherein to plant the seed of the cotton branch of the textile work. An industry which if we estimate from figures of the 1890 census, requires $500,000,000 capital, employs upwards of 290,000 hands, among whom are expended wages annually to nearly if not quite $90,000,000. To-day Rhode Island yields place only to her sister State of Massachusetts, who easily by sheer force of numbers is the leading cotton manufacturing State in the Union. But Massachusetts is more than seven times larger in territory and has seven times our population with only three times the num-

ber of spindles, Rhode Island having more spindles than the Middle States or the Southern and Western States combined.

It was in 1790 that SAMUEL SLATER set up his spinning jenny on the banks of the Pawtucket river. In 1890 there were to be found in this adopted State, the smallest State in the Union, 94 cotton mills representing 2,000,000 spindles, including the largest thread mills in the world as well as the largest cotton and woollen manufactories in the entire world.

But these statistics of employees, wages, spindles and mills do not tell the whole story that is to be credited to the cotton industry. I look over the prospectus of your gathering, and I see that the topics for discussion involve triumphs of mechanism, feats of engineering, sanitary problems, generation and distribution of electricity, and in brief, every branch of the industrial arts and sciences. When we realize that accurate knowledge in these various branches is as important to the proper development of your industry as is the annual crop of cotton, it does not seem an exaggeration to say that the textile interests of this State are in a large degree responsible for the industrial growth in other directions. Yes, and are in fact responsible for the vast hive of human industry which, from Woonsocket on the north to Westerly on the south, finds a livelihood for 800,000 or more individuals. And this great growth may be traced back to that little mill run by water power on the banks of the Pawtucket river.

But you have a long programme and a busy session before you, and I will not trespass upon your time. I am glad to welcome our guests from the Southern and Middle States. The new south is doing much to promote this industry. The cotton States exposition at Atlanta, next autumn, will merit and receive attention from many of us. I give you all a hearty welcome to the State, trusting you will draw as much pleasure from your visit as I know we shall.

The PRESIDENT. Allow me to say in behalf of the Association and the Board of Government, that we are very thankful for these words of welcome, not only as the Governor of the State, but as a member of the Association.

The Secretary read the following communication from the Providence Board of Trade:

PROVIDENCE, R. I., April 24, 1895.

Dear Sir: — The Providence Board of Trade extend to the New England Cotton Manufacturers' Association, now convened in our city, the courtesies of their rooms during the session of the Association.

Very respectfully,

JAS. LEWIS PEIRCE,
President.

At the morning session the following papers were read:

2. Opening Address.
Mr. D. M. THOMPSON, Providence, R. I.

3. Vertical Engines for Cotton Mills.
Mr. RICHARD H. RICE, Providence, R. I.

4. The Ideal Cotton Mill Steam Plant, its Design and Management.
Mr. GEORGE I. ROCKWOOD, Worcester, Mass.

5. A Steam Creed.
Capt. CHAS. H. MANNING, U. S. N., Manchester, N. H.

7. Water Power, its Development.
Col. SAMUEL WEBBER, Charlestown, N. H.

8. Water Power Development and its Cost.
Mr. A. C. RICE, Dayton, O

In the afternoon the members visited the establishment of the Gorham Manufacturing Company, where they saw the manufacture of sterling and plated silverware, and inspected the construction of the buildings, which were designed by Mr. F. P.

SHELDON, a member of the Association, and is the first instance of slow-burning mill construction applied to works of the silver manufacture; and later they visited the Corliss Steam Engine Works, where they inspected the building of engines, under the improved methods recently introduced at these works.

EVENING SESSION, APRIL 24, 1895.

The SECRETARY. The following applicants for admission have received the approval of the Board of Government:

ACTIVE MEMBERS.

STEPHEN L. ADAMS, Treas., Stafford Manufg. Co., Central Falls, R. I.
By Mr. GEO. E. SHERMAN.

GEORGE E. AMES, Supt., Lawrence Manufg. Co., Lowell, Mass.
By Mr. E. W. THOMAS.

GEO. A. AYER, Supt., City Manufg. Corp., New Bedford, Mass.
By Mr. WM. J. KENT.

ERNEST BRIDGE, Supt., Jas. Chadwick & Bro., Ltd., Jersey City, N. J.
By Mr. WM. WHITTAM, JR.

WALTER D. BRIGHAM, Asst. Supt., Willimantic Linen Co., Willimantic, Conn.
By Mr. E. W. THOMAS.

ARNOLD B. CHACE, JR., Agt. Valley Falls Co.'s Woonsocket Mill, Valley Falls, R. I.
By Mr. JAMES P. TOLMAN.

H. S. CHADWICK, Pres., Dover Yarn Mills, Charlotte, N. C.
By Mr. A. F. KNIGHT.

CHAS. OWEN DEXTER, Mgr. Canadian Colored Cotton Mills, Ltd., Hamilton, Ont.
By Mr. F. J. MUIR.

CLARENCE N. CHILDS, Asst. Supt., Hamilton Manufg. Co., Lowell, Mass.
By Mr. E. W. THOMAS.

CHAS. C. DIMAN, Supt., New Bedford, Mass.
By Mr. D. M. THOMPSON.

GEO. OTIS DRAPER, Supt., Weaving Mill, Geo. Draper & Sons, Hopedale, Mass.
By Mr. W. F. DRAPER.

D. M. EHRLICH, Treas., Galveston Cotton and Woollen Mills, Galveston, Texas.
By Mr. E. W. THOMAS.

R. A. GRAY, Supt., Rodman Manufg. Co., Allenton, R. I.
By Mr. D. W. GRAY.

JOHN GREGSON, Supt., Merchants Manufg. Co., Fall River, Mass.
By Mr. E. W. THOMAS.

B. F. GUY, Supt., Pelzer Manufg. Co., Pelzer, S. C.
By Mr. ELLISON A. SMYTH.

JOHN H. HAMBLY, Treas., Quidnick Manufg. Co., Providence, R. I.
By Mr. ROBERT W. TAFT.

JOHN J. HART, Supt., Merrimac Print Works, Lowell, Mass.
By Mr. E. W. THOMAS.

HORACE L. HAYDEN, Agt., Walhalla Cotton Mills, Walhalla, S. C.
By Mr. E. W. THOMAS.

HENRY S. HOUGHTON, JR., Supt., Paul Whitin Manufg. Co., Northbridge, Mass.
By Mr. HENRY T. WHITIN.

ARTHUR W. HUNKING, Supt., Mass. Mills, in Georgia, Rome, Ga.
By Mr. E. W. THOMAS.

J. E. JENCKES, Pres., E. Jenckes Co., Pawtucket, R. I.
By Mr. G. S. HOOPER.

FRED LACEY, Supt., Greylock Mills, North Adams, Mass.
By Mr. Z. D. HALL.

ABBOTT F. LAWRENCE, Treas., Nemasket Mills, Taunton, Mass.
By Mr. FRED C. MCDUFFIE.

DAVID LOWE, Asst. Supt., Parkhill Manufg. Co., Fitchburg, Mass.
By Mr. ARTHUR H. LOWE.

JAS. R. MACCOLL, Agt., Lorraine Manufg. Co., Pawtucket, R. I.
By Mr. E. W. THOMAS.

PHILIP A. MATHEWSON, Supt., Chace Mills, Fall River, Mass.
By Mr. J. A. ATWOOD.

CHAS. L. MACOMBER, Agt., Nemasket Mills, Taunton, Mass.
By Mr. F. C. MCDUFFIE.

A. B. MOLE, Mgr., W. C. Plunkett & Sons, Adams, Mass.
By Mr. ARTHUR H. LOWE.

EDWARD A. MONGEON, Supt., Blackstone Mfg. Co., Blackstone, Mass.
By Mr. CHAS. E. THOMAS.

O. B. PARKER, Supt., U. S. Cotton Co., Central Falls, R. I.
By Mr. A. B. MANN.

ANDREW G. PEIRCE, JR., Treas., Peirce Mfg. Co., New Bedford, Mass.
By Mr. A. F. KNIGHT.

WM. C. PIERCE, Pres., Elizabeth Mills, Providence, R. I.
By Mr. A. F. KNIGHT.

M. A. RAWLINSON, Asst. Supt., Tremont & Suffolk Mills, Lowell, Mass.
By Mr. E. W. THOMAS.

HERBERT H. SHUMWAY, Gen Supt., B. B. & R. Knight, Providence, R. I.
By Mr. JOHN F. HAMLET.

ARNOLD SCHAER, Supt., Warren Manufg. Co., Warren, R. I.
By Mr. J. H. KENDRICK.

LOUIS SIMPSON, Gen. Mgr., Montreal Cotton Co., Valley Field, P. Q.
By Mr. A. F. KNIGHT.

ALBERT A. SWEET, Supt., King Philip Mills, Fall River, Mass.
By Mr. WM. J. KENT.

ROBERT RENNIE TAFT, Supt., Baltic Mills, Baltic Conn.
By Mr. E. P. TAFT.

OSCAR B. TRUESDELL, Agt., Fiskdale Mills, Fiskdale, Mass.
By Mr. A. M. GOODALE.

W. B. SMITH WHALEY, Pres., Richland Cotton Mills, Columbia, S. C.
By Mr. A. F. KNIGHT.

H. D. WHEAT, Treas. & Gen. Mgr., Gaffney Manufg. Co., Gaffney, S. C.
By Mr. A. F. KNIGHT.

ARTHUR F. WHITIN, Pres., Sanders Cotton Mills, Agt., Whitinsville Cotton Mills, Whitinsville, Mass.
By Mr. ALFRED E. ADAMS.

ASSOCIATE MEMBERS.

G. M. ANGIER, Representative, Mather Electric Co., Boston, Mass.
By Mr. A. F. KNIGHT.

GEO. R. BABBITT, Pres., American Oil Co., Providence, R. I.
By Mr. D. M. THOMPSON.

GEO. S. BARNUM, Treas., Bigelow Co., New Haven, Conn.
By Mr. A. F. KNIGHT.

GEO. W. BENSON, Cotton Dealer and Cotton Waste, 36 Purchase St., Boston, Mass.
By Mr. A. F. KNIGHT.

J. PAYSON BRADLEY, The Kehew-Bradley Co., 24 Purchase St., Boston, Mass.
By Mr. A. F. KNIGHT.

D. RUSSELL BROWN, Mill Supplies, Providence, R. I.
By Mr. A. F. KNIGHT.

H. MARTIN BROWN, Mill Supplies, Providence, R. I.
By Mr. A. F. KNIGHT.

JOHN H. BURGHARDT, Mill Supplies, 31 Pearl St., Boston, Mass.
By Mr. E. W. THOMAS.

JAMES BUTTERWORTH, Pres., H. W. Butterworth & Sons, Philadelphia, Pa., York and Cedar Sts.
By Mr. A. M. GOODALE.

MALCOLM CAMPBELL, Gen. Mgr., Woonsocket Machine & Press Co., Woonsocket, R. I.
By Mr. CHAS. H. GORTON.

W. W. CAREY, Machinery Builder, Lowell, Mass.
By Mr. E. W. THOMAS.

FRED A. CHASE, Mill Supplies, 7 Eddy St., Providence, R. I.
By Mr. A. F. KNIGHT.

CHAS. H. CHILD, Treas., Brown Bros. Co., Providence, R. I.
By Mr. A. F. KNIGHT.

PETER H. CORR, Cotton and Cotton Yarns, Taunton, Mass.
By Mr. WM. J. KENT.

R. H. DEMING, Cotton, 10 So. Water St., Providence, R. I.
By Mr. A. F. KNIGHT.

C. E. W. DOW, Agent, Metallic Roll Co , Indian Orchard, Mass.
By Mr. E. W. THOMAS.

WM. H. DYER, Reeds, P. O. Box 451, Providence, R. I.
By Mr. W. B. GOWDEY.

T. C. ENTWISTLE, Manufr. of Cotton Machinery, Lowell, Mass.
By Mr. WM. J. KENT.

D. D. FELTON, Treas., S. A. Felton & Sons' Co., Manchester, N. H.
By Mr. A. F. KNIGHT.

JOHN W. FERGUSON, Mill Engineer, Paterson, N. J.
By Mr. F. C. MCDUFFIE.

J. HERBERT FOSTER, Cotton, 10 So. Water St., Providence, R. I.
By Mr. A. F. KNIGHT.

GEO. A. FULLER, Pres., Stedman & Fuller Mfg. Co., Providence, R. I.
By Mr. D. M. THOMPSON.

ALLAN V. GARRATT, Chief Engineer Lombard Water Wheel Governor Co., 61 Hampshire St., Boston, Mass.
By Mr. E. W. THOMAS.

ROYAL W. GATES, of Josiah Gates & Sons, Leather Belting, Lowell, Mass.
By Mr. A. F. KNIGHT.

W. S. GRANGER, Pres., Granger Foundry & Machine Co., Providence, R. I.
By Mr. A. F. KNIGHT.

WM. B. HAWES, Cotton Yarn Broker, Fall River, Mass.
By Mr. WM. J. KENT.

WM. B. KEHEW, The Kehew-Bradley Co., 24 Purchase St., Boston, Mass.
By Mr. A. F. KNIGHT.

JOSIAH M. LASELL, Asst. Treas., Whitinsville, Mass.
By Mr. H. T. WHITIN.

F. H. MAYNARD, Gen. Bus. Mgr., Gen. Fire Ext. Co., Providence, R. I.
By Mr. A. F. KNIGHT.

GEO. H. MEADER, Manufacturer of Steam Appliances, 165 High Street, Boston, Mass.
By Mr. A. F. KNIGHT.

GEO. B. MORISON, Selling Agt., Hadley Co., Boston, Mass.
By Mr. ARTHUR H. LOWE.

SIDNEY B. PAINE, in charge of Power and Mining Department, General Electric Company, 180 Summer St., Boston, Mass.
By Mr. E. W. THOMAS.

GEO. C. PHILLIPS, Manufg. Tape Dresser, Providence, R. I.
By Mr. A. H. LOWE.

R. H. RICE, Treas., Rice & Sargent Steam Eng. Co., Providence, R. I.
By Mr. D. M. THOMPSON.

C. E. ROBERTS, Mgr., Hartford Steam Boiler Inspection and Insurance Co., 125 Milk St., Boston, Mass.
By Mr. F. C. MCDUFFIE.

HENRY C. SPENCE, Gen. Mgr., Metallic Drawing Roll Co., Indian Orchard, Mass.
By Mr. A. F. KNIGHT.

DANIEL J. SULLY, Cotton Broker, 13 So. Water St., Providence, R. I.
By Mr. WM. J. KENT.

CYRUS A. TAFT, Agt., Whitin Machine Works, Whitinsville, Mass.
By Mr. A. F. KNIGHT.

WM. V. THRELFALL, Selling Agt., Pettee Machine Works, Newton Upper Falls, Mass.
By Mr. F. J. HALE.

G. A. THUDIUM, Supplies, Boston, Mass.
By Mr. E. W. THOMAS.

G. MARSTON WHITIN, Treas., Whitin Machine Works, Whitinsville, Mass.
By Mr. H. T. WHITIN.

The committee appointed to distribute, collect and count ballots attended to their duty, and reported that each of the foregoing received all of the votes cast, and the President declared the candidates unanimously elected.

On motion of Mr. JOHN W. DANIELSON, duly seconded, the following vote was taken:

Ordered, that the Board of Government be instructed to levy an assessment upon the active members not exceeding ten dollars, and upon the associate members not exceeding twenty dollars, for the fiscal year.

The PRESIDENT. The Secretary will give a notice about the dinner tickets.

The SECRETARY. In regard to the dinner tickets it should be understood that the individuals invited are the guests of GOVERNOR BROWN, and others of the Pomham Club, who are also members of the New England Cotton Manufacturers' Association. It is not a dinner to the Association, and is nothing with which the officers of the Association have any part in the arrangements. Dinner tickets will be necessary. They can be provided for you all. It will be necessary to obtain them now of Mr. SULLY, because arrangements must be made before to-morrow. Members, candidates for membership, and those who are guests of the Association.

If any persons have applications, will they please hand them to the Secretary before the meeting is over? It will not be possible to act upon any applications not in by to-morrow.

The following papers were read:

6. Some Thoughts on the Production of Steam, with Special Reference to the Use of Cheap Fuel.

By a Miner of Coal, Mr. ECKLEY B. COXE, Drifton, Penn.

10. Operating by Electricity from a Distance.

Mr. JOHN ECCLES, Taftville, Conn.

MORNING SESSION, APRIL 25, 1895.

The following papers were read:

9. Electrical Driving of Textile Establishments.

Mr. SIDNEY B. PAINE, Boston, Mass.

11. Generation and Distribution of Electric Power for Manufacturing Purposes.

Messrs. C. A. STONE and E. S. WEBSTER, Boston, Mass.

The PRESIDENT. I have received a letter from Mr. F. M. MESSENGER resigning his membership on the Board of Government.

PROVIDENCE, R. I., April 24, 1895.

E. W. THOMAS, ESQ.,

President of the New England Cotton Manufacturers' Association.

Dear Sir: — As it will be practically impossible for me to serve as director on the Board of Government of the New England Cotton Manufacturers' Association for another year with credit to myself or justice to the Association, I hereby tender my resignation as a director of said Association.

Yours truly,

F. M. MESSENGER.

Mr. R. W. EATON. I move that Mr. MESSENGER'S resignation be accepted.

Motion seconded. Voted that the resignation of Mr. F. M. MESSENGER from the Board of Government be accepted.

The PRESIDENT. We will now hear the report of the Committee on Nominations.

Mr. R. W. EATON. The Committee on Nominations were met at the outset by the determination of the present President to retire at the end of this present year, a determination which personally, and I believe that I am in harmony with every member of the Association, I very much regret, a determination which he has arrived at after mature consideration, and he has taken a large part of the burden of the work since the new movement has come in. I, for one, would not feel like urging him to remain.

The following nominations are respectfully submitted by the committee:

For President, A. M. GOODALE.
For Vice-Presidents, WM. J. KENT, FRED. C. MCDUFFIE.
For Director (to fill vacancy), JOHN ECCLES.
For Directors for three years, HERBERT L. PRATT, STEPHEN A. KNIGHT.

The PRESIDENT. Gentlemen, you hear the report of this committee.

Upon motion, duly seconded, it was voted that the report be accepted and that the meeting proceed to ballot.

The PRESIDENT. I appoint Mr. JOHN H. KIMBALL and Mr. JOHN RUSSELL to distribute, collect and count the ballots.

Mr. R. W. EATON. Mr. President, I move that the tellers be instructed to report at the close of the meeting the result of the ballot. Seconded. Voted.

The SECRETARY. I have to present a ballot for candidates which have been proposed during the meeting, and which the said Board of Government did not have an opportunity to pass upon until late last evening.

Second Ballot for Candidates for Membership in the New England Cotton Manufacturers' Association, Providence Meeting. Providence, R. I., April 24, 25, 1895. Voted on April 25, 1895.

ACTIVE MEMBERS.

ALBERT KNIGHT, Supt., Quidnick Manufg. Co., Anthony, R. I.
By Mr. WM. J. KENT.

CHARLES H. MERRIMAN, JR., Asst. Supt., Social Co., Woonsocket, R. I.
By Mr. A. TENNEY WHITE.

ASSOCIATE MEMBERS.

THOMAS G. COX, Selling Agent, Mason Machine Works, Taunton, Mass.
By Mr. JOHN TEMPEST MEATS.

FREDERICK I. DANA, Supt., for Thomas Phillips Co., Providence, R. I.
By Mr. A. M. GOODALE.

WALTER S. HACKNEY, Treas., Gen. Fire Ext. Co., Providence, R. I.
By Mr. D. M. THOMPSON.

DAVID JACKSON, Mfr. Cotton Machinery, Pawtucket, R. I.
By Mr. A. F. KNIGHT.

ARTHUR L. KELLY, Treas., American Fabric Co., Providence, R. I.
By Mr. D. M. THOMPSON.

STEPHEN MINOT PITMAN, Sec., Narragansett Fire Ins. Co., P. O. Box 315, Providence, R. I.
By Mr. C. R. MAKEPEACE.

CHARLES F. RANDALL, Expert in Textiles, 728 Exchange Building, Boston, Mass.
By Mr. E. W. THOMAS.

GEORGE W. STAFFORD, Mgr. Knowles Loom Works, Providence, R. I.
By Mr. JOSEPH H. KENDRICK.

ERVING Y. WOOLEY, Manufacturers' Agent, 152 Congress St., Boston, Mass.
By Mr. WM. J. KENT.

The following paper was read:

13. Humidifying and Ventilating Mills.
Mr. OTTO HOFFMAN, Manchester, England.

Topical Questions No. 26, 27 and 28 were submitted without discussion. No. 29 was discussed. No. 30, no discussion. No. 31, discussion.

Thursday afternoon was devoted to a dinner at the Pomham Club on Narragansett Bay. Hon. D. RUSSELL BROWN, governor of Rhode Island, presided, and at the conclusion of the dinner short addresses were made by D. M. THOMPSON, Esq., Captain JOHN C. WYMAN, ARTHUR H. LOWE, Esq., A. F. KNIGHT, Esq., Lieut. EDWARDS, U. S. N., and the Secretary.

EVENING SESSION, APRIL 25, 1895.

The following paper was read:

14. The Principles of Construction of Card Clothing.
Mr. JOSEPH NASMITH, Manchester, England.

REPORT OF COMMITTEE ON RESOLUTIONS.

Mr. WM. F. DRAPER, JR. Mr. President, for the courtesies and favors shown them by the Local Committee, Local Secretary, Gorham Silver Works, Corliss Steam Engine Company, Providence Board of Trade, His Excellency the Hon. D. RUSSELL BROWN and his associates, the New England Cotton Manufacturers' Association, desire to express their appreciation and gratitude.

This meeting has been an unparalled success, and it is hereby resolved that the hearty thanks of the New England Cotton Manufacturers' Association be tendered to the Local Secretary, Locol Committee, Gorham Silver Works, Corliss Steam Engine Co., Providence Board of Trade, Hon. D. RUSSELL BROWN and his associates, for their untiring efforts to make its fifty-eighth meeting so eminently successful, socially and otherwise.

Also that the Secretary of the Association be instructed to transmit a copy of these resolutions to each of the parties mentioned.

Committee on Resolutions: W. F. DRAPER, JR., H. L. PRATT, F. A. FLATHER, R. R. SMITH, JOHN T. MEATS.

On motion, duly seconded, it was voted that the foregoing resolution be adopted.

The following report was submitted:

12. Equitable Payment of Prices for Weaving Various Styles of Goods.

Report of Committee: { E. W. THOMAS, Esq., Lowell, Mass. / A. F. KNIGHT, Esq., Manchester, N. H.

The Tellers on the second ballot reported that all the votes were cast for the persons named.

The PRESIDENT. I declare that all the persons whose names were on the second ballot have been elected members of this Association.

Topical Question No. 32 was discussed; No. 33 laid on the table; No. 34 discussed: No. 35 discussed; No. 36 laid on the table until the next meeting; Nos. 37, 38 and 39 discussed.

Mr. JOHN TEMPEST MEATS. Mr. President, before this meeting adjourns I would like to make a motion, and my object in so doing is to save time and promote a more intelligent discussion of the subjects at these meetings. The motion is, In order to save time and promote a more intelligent discussion of the subjects presented at the meetings of this society, I move that the Board of Government be requested to consider the propriety of requiring that all papers, to be read at its meetings, be presented to the Secretary sufficiently early to enable him to have them distributed to the members not less than one week prior to such meeting.

The PRESIDENT. That rule was in force at one time.

Mr. A. F. KNIGHT. Mr. President, he simply suggests that the Board of Government take the matter in hand. I am a member of other societies. The time taken up in discussion is usually much more profitable than the papers received.

The SECRETARY. Mr. President, I will say that the Secretary, by order of the Board of Government, wrote at once to every person who had arranged to give a paper for this meet-

ing, requesting copy of manuscript, and as a matter of fact, two copies, only, were received in time to be printed.

It was then voted that this resolution be adopted.

The SECRETARY. Mr. President, the report on the officers on the ballot has been handed in to the table.

The PRESIDENT. The total number of ballots is seventy-two, all for A. M. GOODALE, *President;* WM. J. KENT, FRED C. MCDUFFIE, *Vice-Presidents;* JOHN ECCLES, HERBERT L. PRATT, STEPHEN A. KNIGHT, *Directors.* I declare the gentlemen duly elected, and it gives me great pleasure to introduce to you your new President. (Applause.)

PRESIDENT GOODALE. *Gentlemen:* — I thank you sincerely for the honor you have done me in electing me President of this Association. I am able from my experience on the Board of Government to realize partly the amount of work necessary to maintain the high standing of the Association, but I am able to realize fully that no matter how hard the Board of Government may work, they cannot make a success unless they have the hearty co-operation of every member of the Association.

In a very short time the new Board will commence to prepare for the October meeting, and I know that I voice the sentiments of each member of the Board in asking that you will honor at sight our requests for papers and subjects for topical discussion. In this way, and in this way only, can we do the work that you expect of us.

I hereby declare this meeting adjourned without day.

Adjourned.

C. J. H. WOODBURY,
Secretary.

TRANSACTIONS.

MORNING SESSION, APRIL 24, 1895.

The PRESIDENT. The opening address this morning will be a welcome to the visiting members, and also a paper on Power by Mr. D. M. THOMPSON of Providence, the Chairman of the Local Committee.

OPENING ADDRESS.

BY MR. D. M. THOMPSON, CHAIRMAN OF THE LOCAL COMMITTEE, PROVIDENCE, R. I.

Mr. President and Members of the New England Cotton Manufacturers' Association —

On behalf of the local committe who have had in charge the arrangements for this meeting, I desire to express to you their royal and hearty greeting and bid you welcome to the city of Providence.

It has been the desire of this committee, as also of all local members, that your meeting at Providence shall prove a memorable one in the history of the Association. To this end the most active interest has been manifest, and every effort has been made to render your brief visit one of much pleasure to you all.

We wish you to feel that this committee, its secretary, and all of the Rhode Island members are at your service.

You have received a very cordial welcome from his excellency GOVERNOR BROWN. I may add that the committee had also invited his honor MAYOR OLNEY, of Providence, to be present at this meeting, and I am permitted to express to you, in his behalf, a most hearty welcome, and his sincere regrets that he is unable to meet you upon this occasion.

The committee have arranged for your entertainment this afternoon, first, a visit to the Gorham Manufacturing Co. The electric cars will leave the Narragansett Hotel at two o'clock; at four o'clock the members and friends will leave the Gorham Manufacturing Co. for a visit to the Corliss Steam Engine Co.'s works, returning from there to the Narragansett Hotel at six o'clock. To-morrow afternoon you will be entertained at the Pomham Club, a beautiful summer resort on Narragansett Bay, as the guests of GOVERNOR BROWN and others, where a clam dinner will be served in true Rhode Island fashion. The electric cars will leave from Mathewson street, in front of this Hall, at one o'clock. All are requested to be promptly on hand at the time indicated, so as not to obstruct the regular street car service.

The President has announced that the first paper, upon "Power," will be presented by Mr. THOMPSON. I made a request to be excused. I will, however, say a few words, and at some future time present the subject of Power in a more formal manner.

The question is one of more than ordinary interest, since power has contributed more than any other single agency in the progress of our civilization. The vegetation upon the earth, the products of combustion buried beneath its crust, the waters in oceans and rivers, the weight of our atmosphere, the heat of the sun which has for ages enveloped all matter within our sphere, united with the immutable and unchanging laws of nature, constitute the sources of physical, chemical, electrical and mechanical energy. This energy, when utilized through

the agencies discovered by man, we call power. The energy of water in a flowing stream, and then as a falling body, we call water power. It continued for centuries the only known or available force applicable to useful work. It is scarcely credible that water converted into steam and utilized for power through the agency of the so-called steam engine, is of so recent origin. It is the product of the 18th centnry. It is but 134 years since the Newcomen engine in its improved form, and extensively used for pumping water from mines, required fifty-seven pounds of coal per indicated horse power per hour. The improvements and inventions of Watts, beginning in 1764, revolutionized the world and laid the foundations for Hargraves, Arkwright, Wilson, and Cartright, in their introduction of machinery for cotton spinning and its manufacture. Second only to Newcomen and Watts, is the work begun by Trevethick, finished and made practicable by Stevenson, which rendered it possible to distribute by steam railways the products of industry at a cost which the most vivid imagination had not before conceived.

We have, until recently, regarded our opportunities as narrowed within a limited sphere, and in dealing with our power, it has been simply a question of the economical methods of operating that which we possess. Until within the past few years we have regarded both water wheels and engines as having attained a stage of almost admitted perfection. It is now nearly thirty years since water wheels were tested which gave a useful effect of eighty per cent. of the theoretic value of the water.

Water power has been improved in the economy of wheels but slightly, except that the average of all wheels now built has been raised to a stage of greater excellence, there being now a relatively larger number of high grade than formerly. The horizontal wheel is a marked improvement, and should be adopted wherever possible. The introduction of the compound and triple expansion engines is in the line of the general progress of the times. This change marks a period of great interest in the question of power. It is of importance to those using

steam power, since it affords an opportunity to greatly reduce its cost. In the case of simple condensing engines at the present time, twenty-one pounds of water per indicated horse power, may be regarded as economical, though under especially favorable conditions, about five per cent. better results have been obtained. In the use of simple high pressure engines, twenty-seven pounds of water and three pounds of coal per indicated horse power, may be regarded as a fair economy, subject in special cases to a reduction of five per cent. As a substitute for the simple condensing, the compound condensing engine enables a saving of thirty-three to thirty-five per cent. of fuel, and the compound non-condensing engine will ensure a saving of twenty-five to twenty-eight per cent., as compared with the high pressure or simple plain engine.

There is another phase of the question to be considered, in that the greatly reduced cost of steam power changes the relative values of steam and water power. There were formerly cases where the steam power mill was at a disadvantage, owing to the less cost of water power, others in which the benefits of location gave the advantage to the steam mill, and still others where the several conditions balanced each other. In any or all locations, and whatever the physical conditions, the improvement in steam power counts by so much against the water power and reduces its value for motive power as compared with steam. In the case of water power plants, it is a simple question of charging off the loss or difference, as depreciation. The advantages of water power derived from its early operations, have made the original investment a good one, and its future employment in such cases, becomes a matter of no serious concern.

In the case of the establishment of new plants there is but little inducement to seek sites for water power for direct application, where power is the chief object or determining factor. In other words, water power to-day has no advantage sufficient to justify the selection of a site which would involve fifty miles

of railroad transportation, more or less, according to circumstances. There may, however, be found at such distant points, other advantages, such as the reduced cost of real estate, nominal taxes, more abundant help or less cost of living, the quiet and retired conditions under which operatives would be more contented, and less liable to be affected by the influence of labor agitation. It may, however, be said that with any given location, all other considerations being upon equal terms, water power will be the cheapest. It is impossible to provide an exact unit of measure which shall determine the relative merits of the matter of location, where power is the question to be considered. Each case must be determined individually, and with reference to a fair consideration of all phases of the subject.

A water power is, therefore, more or less valuable according to various conditions which are found to exist. The value of water power varies to a considerable extent, according to the physical conditions which have to be dealt with in the construction of dams, bulk-heads, fore-bays, wheel-pits, and race-ways. In this connection, the head and fall, as also the quantity of water and the reliability or uniform flow of the stream, are factors of the greatest importance. There are cases of comparatively low falls and a moderate supply of water, where the physical conditions are such as to render the cost of development almost prohibitive. In such a case the power may be practically worthless, however valuable the location may be from other points of view. At other sites the reverse may be found, where there is a high head, a large amount of water, a uniform supply, and exceptionally favorable conditions in the matter of construction; in such cases the water power becomes exceptionally valuable.

Again, the character of the business very largely determines the question of location, independently of the cost of power. If the sites shall be selected solely for the purpose of utilizing water as power, then the several considerations above cited must determine its relative value as compared with steam. If,

however, the business shall be such as to require a considerable amount of water for manufacturing purposes other than for power, as in the case of bleacheries, dye and print works, or as in woollen mills where the amount of power as compared with the capital expended in plant is very much less than in cotton mills, then, in such cases, the conditions are so greatly changed that a so-called water power may become very valuable; but chiefly for the water, and independently of its head. If there is sufficient water for all purposes except power, then power may be supplied with steam at a nominal cost, since a large amount of steam is required for manufacturing purposes, independent of power. Under these conditions, the cost of steam power involves only the cost of engine, interest, supplies, attendancc, and that proportion of fuel which represents the difference of heat units between steam at the initial pressure and that at the back pressure or exhaust of engines plus the loss due to condensation.

In this connection it may be observed that the nature or character of the business may determine the type of engines to be employed, even in strictly steam power plants. The larger the amount of power required, the greater the opportunity and necessity for saving. If but a comparatively small amount of steam is required for other purposes than power, then a compound condensing or triple expansion engine should be used. If the location is at a point where there is insufficient water for condensation, then, in most cases, a compound, non-condensing plant should be installed, since the saving of fuel, as compared with simple non-condensing, will be eighty per cent. of that obtained by the use of the compound condensing as compared with the simple condensing engines. If, however, the nature of the business is such as to require more than half of the steam used for power in the compound condensing, then it will be advisable to use the compound non-condensing engine. If the business requires all of the steam that would be necessary for power in a simple engine, then in most cases the sim-

ple high pressure engine should be used. The question of the relative values of the several types of engines may be determined by the cost of fuel necessary to produce steam for all purposes, power included.

There is a feeling which prevails to a considerable extent among steam users, that the cost of a modern steam plant upon the system of compound or triple expansion engines involves so large an increased expenditure for the plant that the saving of fuel becomes a matter of doubt. This, however, is an error which a moment of reflection will readily remove. In the case of a strictly steam power plant of 1,000 horse power, using a simple non-condensing engine upon average good conditions of twenty-seven pounds of steam per indicated horse power, then it is clear that 1,000 horse power of boilers would be required. This would allow but a slight percentage of evaporating capacity over the ordinary conditions of running, since the boilers are rated upon an evaporation of thirty pounds of water per horse power per hour, with feed water at 100 degrees and seventy pounds of steam pressure.

If we change the above conditions and put in an engine to run simple condensing, we shall save a very considerable part of the expenditure required in the first case cited. This saving will amount to very nearly twenty per cent. on both engines and boilers, less the extra cost of the condensing plant. We should, therefore, require an engine of smaller size, and save nearly 200 horse power of the boilers. In the case of a compound condensing plant, we should require not exceeding fifty-five per cent. of the amount or capacity of boilers, and in the case of simple non-condensing, not more than sixty-seven per cent. of the capacity of boilers required in the simple non-condensing system first cited. To this, however, must be added the extra cost of condensing machinery, and in the case where the original power was obtained in one engine we must add the extra cost due to the use of two cylinders. But the general proposition holds good, and is applicable to nearly all condi-

tions (with the slight modifications as above indicated) that the saving in the cost of the boiler plant will pay for the increased cost of the engines.

It will thus be clearly seen that whatever difference results in the amount of coal required, as between the several systems, it will be a clear and absolute saving. The saving in the cost of power obtained by the system of compounding may be further extended into the triple expansion engines. The difference, however, becomes less marked than in the cases above cited, and except for units of very large amount it may be seriously questioned if the saving of ten per cent. justifies the additional cost. This, however, can only be determined by a consideration of local conditions. The amount of water required for condensing purposes is in the ratio of twenty-five pounds of water to one pound of steam under average conditions. Hence there may be cases where there is a supply of water inadequate for simple condensing, which would be sufficient in the case of compound or triple expansion.

In determining the cost of steam power, while the engine is a principal factor in the problem, the value of which depends upon its economy and efficiency in operation, yet there are other conditions of equal importance and which should demand equal attention. The effective value of the engine must be referred to and ascertained from the quantity and quality of steam used in the performance of its duty. It is not only misleading but is manifestly unfair to state the performance of an engine in pounds of coal per indicated horse power without accompanying the proposition with a full and clear statement of the operation and economy of the boilers. An engine builder could not guarantee his engine upon a basis of coal consumption without a full and accurate knowledge of the economy and efficiency of the boilers. Hence he must refer the matter to a given amount of steam of a certain quality. The quality of this steam enters into consideration as a most important factor. There are types of boilers which may produce steam economi-

cally so far as may be determined by evaporation tests in which quantity of water evaporated is the sole consideration. If, however, as in very many cases, this steam possesses from two and one-half to four per cent. of moisture or saturation, this moisture must be credited to the engine, so as to make good the demand for absolutely dry steam.

The quality of the steam enters into the problem of economical performance of the engine to a greater degree than is generally supposed. As a matter of fact, even absolutely dry steam (a condition seldom found in general practice and impossibie in many types of boilers) falls far short of the ideal conditions which should obtain in all cases where steam is used for power. This condition is especially true in the case of high pressure necessary to compound or triple expansion systems. The increase in pressure means higher temperatures, and consequently a greater difference in the temperatures of cylinders at admission and exhaust. Steam absolutely dry, unaccompanied by entrainment of water and superheated to the highest possible point (not less than forty degrees), should be required, in order to secure the highest economy and efficiency of engines, the necessity for which is apparent in view of the enormous loss by condensation. This is a condition which is receiving more consideration than formerly, and one which will compel attention in the near future.

It is generally an accepted proposition, that the boiler is an important factor in securing a low cost power. You may have a good economical engine, but a low cost of power will be impossible without an equally good and economical boiler plant. You may have ideal conditions in respect to both, and then fall short of economical results through inefficient service. The best results can only be secured through the most careful attention and the service of careful and faithful employees. It is by far too common in practice, that a man is employed as a fireman in the boiler room because of his inefficiency elsewhere, or that it requires only physical energy to shovel coal. A greater

mistake cannot be made. There is no department within the sphere of textile mill work, the amount of labor considered, where it is possible to effect a greater saving or involve a larger loss, than is to be found in the fire room.

Intelligent labor should be employed and paid sufficiently well to ensure the most faithful service. Boilers should be put into and maintaied in the best possible condition. Firing should be regular, systematic, frequent according to fuel used, and always prompt, since fire doors should be open for the least possible time. Boilers should be kept clean. If tubular, of whatever type, they should be more frequently cleaned than in general practice. Interiors of boilers should be frequently inspected, and cleaned whenever there is occasion therefor. All boilers should be fed through meters adapted to the work performed, occasionally tested, and a daily record made of the amount of water evaporated. This will secure a much needed check upon the operation of the boilers, detect waste or leaks, and will call immediate attention to the failure of proper fire service, or, when compared with the record of coal used, will disclose its relative value. If the boiler department shall be run upon such careful system as is common to many other departments of our mills, not only will there result a large saving under any conditions, but it will easily determine the real value or defects inherent in the system.

The question of power involves conditions outside of an economical boiler and steam engine plant or water power. There is a large consumption of power in the friction of main belts. In the average practice of engine or wheel builders, there may be found in use a factor for double belts under favorable conditions of distribution as low as 400 feet per minute, per horse power per inch of belt, and frequently less. This involves a tension of belt not excessive as compared with its tensile strength, but such as to produce a needless friction in journals, and a consequent waste of power. This general principle holds true throughout the entire equipment of a plant. Rope-driving as

now applied is worthy of careful investigation to determine its relative value in the matter of power, as also the cost of its maintenance.

The speeds of shafting and the sizes of pulleys are of vital importance. Within the range of usual practice shafts should be made of minimum diameters, subject to safe factors for lateral and torsional strains. The speeds should not be extended to a rotation beyond the absolute requirements for transmission. The diameter of shafts and pulleys, the velocity and tension upon belts, the distance between journals and the weight of all parts, are points which demand the most careful consideration. In other words; the difference in consumption of power through the friction of shafting may easily vary to the extent of two and one-half to four per cent. of the total power required. This makes a difference of from eight to twelve per cent. of the actual power required for shafting transmission. In the matter of speeds it should be remembered that with equal weights or loads, the power varies as the square of velocities, so that to double the speed, reqires four times the power. It is therefore a matter of the first importance to regulate with great care both the weight and velocity.

The consumption of power in the friction of shafting justifies an early consideration of the question of the adaptibility of ball or roller bearings. I have no doubt this may be done to a considerable extent, and will result in a large saving of power; but to what extent it may be carried, remains to be determined from further experience.

There are a few cases which afford a conspicuous illustration of the system of roller or ball-bearing journals: The Brown & Sharpe Machine Co. of Providence, have a rolling mill for rolling steel plates three inches wide. It is provided with a six inch face pulley. In practice it was found to be necessary to use a six inch single belt with a four inch rider. The tension of belt required to do the work produced such resistance and friction in the journal boxes, and consequent heating, that

several hours a day were lost. They were upon the point of buying another machine in order to do the work required, when it was proposed to put on some roller bearings. The change was so marked that the work has since been done with a two inch belt, and the mill runs constantly through the day with largely increased product and without the slightest heating of the journals. This system may be readily applied to all jack shafts, main head shafts, and doubtless to all bearings of main line shaftings.

I have found a considerable saving of power in the use of larger pulleys than usually made for individual machines. I have in many cases increased the sizes from twelve to twenty per cent. This method should be applied to all pulleys and belts employed in the minor distribution of power, so as to secure the highest practicable belt velocity consistent with the minimum strains upon journals, and the consequent saving in friction.

I have of late been led to view with considerable favor the use of the Holmes Fibre-Graphite bearing, as a means of reducing the average friction of journals; if successful a much needed improvement will be obtained through the removal of oil stains.

In this connection I may say that Mr. Holmes has recently placed upon the market a new pulley, which he proposes to build in sizes from the smallest up to forty-eight inches diameter, and of any width of face required. The pulley is called a "truss arm fibre rim pulley." The claim is made that it is not more than one-third the weight of iron pulleys for the same service, and has a traction of at least thirty per cent. more than iron pulleys, and considerably more than leather or paper covered ones, while the cost is represented to be very much less than either iron or wood rim pulleys. They are subjected to a chemical treatment which secures a permanency of structure, and are unaffected by the action of temperature or atmospheric conditions.

There are many other phases of the question of power, any

one of which might be useful, instructive and profitable to investigate, such as the merits of the several types of boilers, the different forms of engines, as in the case of horizontal and vertical; also the relative economies of the several types of engines now in use, all of which are worthy of consideration; but space forbids my further comment, while other considerations restrain me upon the present occasion.

There is to be presented to you the subject of electrical power transmission. It is a question of interest because of its novelty, and more especially in view of recent successful applications to mill work, and the strong claims which will be presented in its favor by one who has had a large experience in electrical engineering. I have, as yet, insufficient experience in its use or observance of its operations, to justify a discussion or the expression of an opinion as to its merits as compared with the standard methods. It is in no wise a competitor with either steam or water power, except so far as it is practicable to concentrate larger units of power from either source, and re-distribute the same to the exclusion of numerous smaller plants. I have examined with much interest the installation at the Columbia mills at Columbia, S. C., where it is in operation. The management of these mills express their highest approval and satisfaction with the system. I have no doubt there are cases where it may be employed profitably, and where the advantages of concentration at more favorable and advantageous locations may justify the large expenditures and loss in re-distribution, as in the case of the Peltzer Mfg. Co., at Peltzer, S. C., where they have a large and valuable water power several miles distant from the original mills, and inaccessible for railroad facilities. This plan of electric transmisssion enables them to assemble all the mills at a central point. It is a subject worthy of careful study and will doubtless invoke much future discussion. I would not question that the time will come when the system of electrical transmission will become sufficiently advanced and improved so as to justify its universal adoption. It may yet be possible to

extend and multiply its sub-divisions, so as to remove the present method of shafting transmission and apply the current direct to individual machines. It is truly an ideal condition, and one which will be most cheerfully welcomed. In the light of the marvelous achievements of the past eighteen years, we may safely rely upon still greater advancement in the future through the agency of this hitherto unknown power or subtile force so recently discovered by electrical science. We have, however, to deal with the questions of the hour, accepting such changes as may be presented and which are shown to be justified upon the lines of our past experience.

The PRESIDENT. The next paper is on "Vertical Engines for Cotton Mills," by Mr. RICHARD H. RICE of Providence, R. I.

VERTICAL ENGINES FOR COTTON MILLS.

RICHARD H. RICE, PROVIDENCE, RHODE ISLAND.

Vertical engines are at present exciting some attention, more especially in electrical circles, owing to their increasing use for large central station work. Several of these stations have recently been installed with complete sets of vertical engines; notably, in New York, Chicago and Cleveland. For textile mills there are as yet no large plants in this country furnished with them; but in England and on the Continent many engines of this type have been put in. American cotton manufacturers no doubt follow with interest progress abroad in this line, and many are conversant with the extent to which they are in use, and there is, undoubtedly, considerable interest in this subject. The type is one possessing some advantages over the usual horizontal arrangement, some of which it is the purpose of this paper to set forth.

The term "Vertical Engine" in this paper refers to engines of the inverted vertical type, having the cylinders in a vertical position and above the shaft.

The advantage of the vertical position of the cylinder, in eliminating that part of the piston friction due to the weight of the piston and rod, was early recognized by steam engineers, and, in fact, all the early engines, except perhaps locomotive engines, had the cylinders arranged in this manner. In pumping engines this arrangement is still the favorite for plants to be operated with maximum economy, and on shipboard hardly any other arrangement is met with.

The piston-bearing in the cylinder, being necessarily enclosed, and therefore out of sight, is the most troublesome bearing upon the engine. Its lubrication is necessarily uncertain,

being dependent upon the oil carried by the steam depositing upon the surfaces to be lubricated, and any cutting or abrasion opens a path for leakage of steam and consequent decreased economy, while restoration of the surfaces by re-boring of cylinders is expensive, limited in possible amount and productive of delays.

When the cylinder is placed upright the piston friction is reduced to the slight amount necessary to set out the packing rings, and the oil necessary to lubricate is largely reduced in amount, less oil being needed on account of the diminished friction, and the oil being uniformly distributed over the cylinder walls at each stroke; whereas, in the horizontal cylinder, the piston scrapes the oil away into the exhaust port.

The piston practically floats in the cylinder, the walls and packing rings wear smooth and keep tight for long periods, the expense for repairs is reduced and the economy of operation is maintained.

In case it is desired to use a surface condenser with the engine, the largely reduced quantity of oil to be removed if the engine is vertical will make the problem of its removal considerably simpler. This is probably the reason why the surface condenser is so much more successful on shipboard than it has been on land.

An element of reduced risk in these engines is the lack of necessity for re-adjustment of the piston to a central position in the cylinder, reducing, as it does, the number of enclosed parts, and consequently the liability to accident through their working loose.

An important feature of the usual designs of these engines is that the engine is practically self-contained, and it therefore depends to a very small extent on the character of the foundation for its permanence of alignment. On shipboard the engine is placed on a very flexible support — the ship's framing — and enormous powers are successfully developed at high rotative speed. Marine engines are reduced in weight to the great-

est practicable extent, and with the increase in metal possible in land practice and the extra stiffness which may be attained thereby, it is readily seen that any defect in the foundation would have a much smaller effect than on the horizontal type, where the foundation is very largely relied on to preserve the parts in their proper relations to one another.

A marked defect in the design of stationary verticals has been the lack of recognition of the fact that the framing must be relied on to prevent vibrations, and these parts have often been made of light and flexible shapes, ill suited for stiffness.

Box sections of ample dimensions should be used throughout in bed plates and frames, and with this precaution there is no difficulty in making steady and smooth running engines even if settlement of foundations should occur. By virtue of the limited floor space occupied by the bed plate, also, the area of ground covered by the foundations is correspondingly smaller, and greater precautions can be taken to ensure solidity. The foundation for a cross-compound or triple expansion engine can usually be concentrated into a single large mass, instead of being divided into two independent, comparatively long and narrow masses. Owing to this concentration and the smaller area occupied, the cost of the foundation is materially less than that for the equivalent engine of the horizontal type.

The small floor space occupied by these engines has forced their adoption in stations located in cities where ground rents are high. It is possible with this arrangement to produce large powers upon very limited floor areas. A recent design for a cross-compound engine of 2,000 horse power occupied a rectangle measuring 18 by 14 feet, exclusive of wheel and out-board pillow-block. The equivalent horizontal engine would have occupied nearly twice as much room.

This is not so important a matter in cotton mills, where size of engine room is usually of small moment, land being in such locations cheap; but even here circumstances may arise which

render it of importance, as when, for instance, it is desired to install a new engine in an old mill, with the least possible disturbance of existing conditions. In such cases the compactness of the vertical engine is an important advantage and may determine a decision in its favor. Small floor space also means a smaller and cheaper engine house, the increased height necessary being much more than offset by the diminution in ground plan dimensions. In case it is desired to cut costs to the extreme a monitor may be constructed in the roof, of sufficient size to admit the cylinders, giving excellent light for the examination of the valve gear; but, of course, increasing the labor of removing cylinder head and pistons.

Considering, now, the disadvantages of these engines, we find that their first cost is considerably greater, and there is a loss of accessibility to important working parts. The latter objection is reduced by careful attention in the design and the use of proper hoisting rigging, and first cost will diminish as the type comes more largely into use, rendering it possible to sytematize the manufacture of parts, as is now done in the shops of all first class horizontal engine builders. Each engine now constructed is so special, to meet the conditions imposed, and duplicate orders are so rare that manufacture in quantities is well nigh impossible. Each has an entirely new set of drawings and patterns, and the parts must be carried through the shop in lots of two or three, in place of twenty-five to one hundred as usual. However, under the most favorable conditions, there will always remain a difference in cost in favor of the usual arrangement.

As to the question of economy, vertical engines are usually made with short strokes to economize height, and in so far possess greater clearance spaces. This is, in practice, offset by the permanent tightness of the piston and by the largely decreased internal friction of the engine. Special arrangements of valves, which may be placed in the heads, owing to the infrequent necessity for internal examination of vertical cylin-

ders, will reduce clearances, and it seems reasonable to anticipate a somewhat smaller fuel consumption per horse power delivered in the mill for these engines; but, even granting equality on these grounds, we are still left with the advantages due to lessened depreciation, smaller expense for renewing and maintenance, and greater reliability of operation; advantages which should secure them a favorable reception in installations of the highest class.

The PRESIDENT. The subject of the next paper is, "The Ideal Cotton Mill Steam Plant, Its Design and Management," by Mr. GEORGE I. ROCKWOOD of Worcester, Mass.

THE IDEAL COTTON MILL STEAM PLANT: ITS DESIGN AND MANAGEMENT.

GEORGE I. ROCKWOOD, OF WORCESTER, MASS.

In buying steam machinery and fuel-saving devices the question to be mainly considered is, What relation exists between the cost of the fuel saved and the money outlay for extra cost, attention and depreciation? Really, the crucial test of the value of much apparatus urged by salesmen upon the attention of the purchaser as fuel saving is not primarily its ability to save fuel, but its ability to save money during a term of years. If the expense of the coal to be saved is equal to the charges for labor, interest and depreciation, it is best to purchase.

I make these preliminary remarks to call your attention to

the fact that the most valuable — and hence ideal — steam plant is not necessarily that aggregation of machines and devices producing the most economical use of fuel; to the fact that it is by no means to be taken as a foregone conclusion that because a certain device saves, say, 10 per cent. of the fuel, it is therefore necessarily a wise investment, more especially as there are frequently different ways of effecting this saving of 10 per cent. in the fuel cost, some of which require a far larger cash outlay than do others.

In what follows I will attempt to outline briefly the important characteristics of the main elements of the cotton mill steam plant, dwelling more particularly on the details of the engine best adapted for such work. Let us then consider the elements of a plant of, we will say, 800 indicated horse power.

In the first place, the building should be specially designed to contain the machinery, and should have one high story in the boiler room and two stories in the engine room portion of the plant. This building should be designed with strict reference to the needs for daylight and space of the machinery to be placed in it. To this end it is often convenient to put a wide monitor lengthwise of the building, above a hip roof, making the monitor roof of glass, to give light upon the top of the machinery and boilers.

There should, if possible, be an engine of the horizontal slow-speed type, one engine on either end of the crank-shaft, with parts designed sufficiently heavy and ample to enable either side of the engine to carry the entire load of the mill should any accident occur rendering the other side of the engine for the time being inoperative. The boilers should be either horizontal return-tubular with brick setting, or else Manning upright boilers, which, as they are internally fired and hence require no expensive brick setting or annual expense for mouth-pieces, and furnish superheated steam to the engines, are, so far as these advantages go, preferable to horizontals. The same observations are true of the Corliss type of upright

boiler. Of the Manning boiler it should also be said that the degree of satisfaction which it will give in a long period of operation depends much—very much—upon the spacing of the tubes in the tube sheets, upon the convenient location of hand-holes, and upon the proportion of water-heating surface to grate surface. With excellent design and material these boilers will last many years without requiring outlay for repairs, besides which their chief points of superiority over the horizontal type lie in lower first cost and less space occupied.

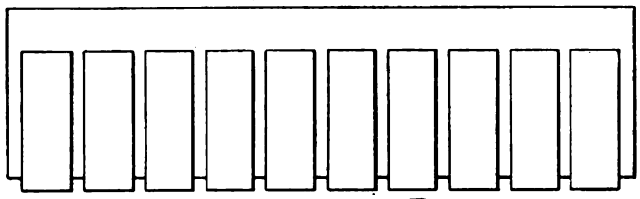
The question of the best type of boiler to be used in a given location is complicated by the mechanical advantages which one kind may have over another. In receiving bids from the manufacturers of the different types, it is well to have each submit also a draft showing the floor space occupied, the water-heating surface and the steam-heating surface of the boilers to be furnished, and the buyer may then estimate also the interest and annual expense for maintenance. He is then in a position to judge between the different makes as to whether the superior mechanical advantages of a particular kind will offset the greater cost.

The drawing (page 98) shows three different batteries of 1,200 horse power each, together with the first cost, expense of maintenance, and water heating surfaces. This comparison is favorable to the upright fire tube boiler, both in the matter of smallest cost and smallest space occupied. The water tube type has certain mechanical advantages which by some are thought to outweigh their extra cost.

There should be at least three ways of putting the feed water into the boilers, namely, by a triplex power pump, an injector, and a duplex steam pump. The steam pump is simply for use in case of accident either to injector or triplex power pump, and should be used instead of the injector if the triplex fails to operate while the engine is running, but should not be used at other times, as the injector heats the water before pumping it into the boilers; which, of course, the engine being shut down,

1200 H.P.
in
THREE DIFFERENT TYPES OF BOILERS

SPACE OCCUPIED 1672 SQ. FT. WATER HEATING SURFACE=18086 SQ. FT.

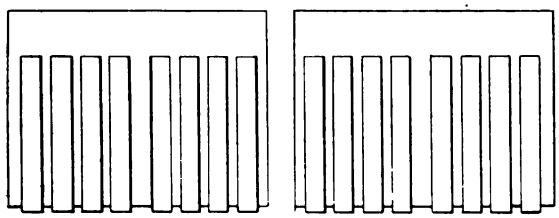


HORIZONTAL FIRE TUBE
COST $10.000. MAINTENANCE OF BRICK SETTING $600.

SPACE OCCUPIED = 540 SQ. FT. WATER HEATING SURFACE=16686 SQ. FT.

VERTICAL FIRE TUBE
COST $12,000. MAINTENANCE OF BRICK SETTING $0.

SPACE OCCUPIED=1495 SQ. FT. WATER HEATING SURFACE 14,320 SQ. FT.



WATER TUBE
COST $25,000. MAINTENANCE OF BRICK SETTING $300.

the duplex pump cannot do. This, however, may not be invariably the case, as there may be other sources of hot water beside the regular feed-water heater, which derives its heat from the exhaust or receiver steam from the engine.

It is a valuable thing for the engineer in charge of the plant to conduct a running test of the coal and water consumption,

getting his facts each day in the year, and to this end a water-meter should be placed in the path of the feed-water just before the pipe rises to the boilers. Before putting the meter in place, it should be carefully calibrated and the correction for different temperatures of feed recorded. Thus a daily account of the amount of steam made can be kept, to be a constant check on the efficiency of the plant.

In a boiler plant of 800 horse power it is a wise investment to bring the coal to the furnace doors mechanically, using for the purpose steel cable elevators and horizontal conveyors to carry the fuel from the coal storage building to the boilers. A coal hopper of 12 tons capacity should be placed in front of each boiler, having a 16-inch delivery pipe to discharge the coal on to weighing scales. The use of the coal hopper discharging from above facilitates much the loading of the coal on to the weighing scales, while it also economizes room. The same elevating and conveying apparatus should be arranged to remove the ashes from the boiler room. The extra cost of elevator, conveyor, etc., for such a plant would be about $2,200, while the saving amounts to the wages of one man, the smaller space occupied, and the general neatness and the ease of weighing the coal. It does not seem to me wise, on the other hand, to stoke the boilers mechanically, as the extra cost for machinery is at least $5,000, while neither wages nor fuel are saved over hand-firing in a plant of this size, neither are there other compensating features incident to the use of stokers. This statement only applies to plants burning bituminous coal.

I believe it is a wise investment of money to buy all high-pressure boilers, steam piping, and engines of such designs and proportions as will fit them to work under a steam pressure of at least 150 pounds. This advice is given in the face of a quite prevalent feeling (the result, perhaps, of much bitter experience with fittings subjected for long periods of time to the high pressure named,) that the best pressure is nearer 100 pounds than 150 pounds. I cannot help thinking this feeling

is also a result of financially squeezing the contractors who furnish these items, especially in these times, as it is actually a by no means difficult or costly feat to design and erect boilers and piping capable of standing for years under 150 pounds pressure without "weeping" at the joints. Steel castings of homogeneous texture, machined and delivered in New England for 6.25 cents per pound, make the best pipe for the weight and money, being vastly better than lap-welded pipe with screwed fittings. Steel boiler flues, riveted to extra heavy cast iron flanges, also make a thoroughly reliable job if properly done. If corrugated copper gaskets are used instead of any kind of soft packing, or, indeed, if the faces of the flanges are nicely surfaced, there will be no trouble in dealing with the high pressure.

All gate valves, of whatever size and kind, should be flange fitted instead of screwed joints, as these valves are liable to have their seats scratched or indented at any time, and the uncoupling of flanges is far easier to do than to take a screwed fitting out of the pipe line. Every boiler should have two blow-off valves in the blow-off pipe, to insure tightness and convenience of repair with pressure on the boiler. The outside valve can then be taken off and refitted or replaced at any time.

In general, with regard to piping, it may be said that every fitting of whatever kind and wherever located should be so arranged as to be easy of access and easy to repair. This, however, is the most frequently sinned against principle of any of the important principles of power-plant design.

In the matter of providing for expansion and contraction of piping, it is important to avoid, if possible, the use of expansion joints, either of the diaphragm or the mechanical slip-joint sort, as these things are troublesome and may become dangerous. When possible and convenient elbows are best made of bent pipe, employing as large a radius as convenient up to 8 feet.

The feed water should be passed first through a pressure heater located in the exhaust pipe from the low pressure cylin-

der; it should then be passed into an open heater of some good type, such as the Weir, Worthington, or Warren Webster design, and here heated with receiver steam to a temperature of 212 degrees, after which operation it may go to the boilers. Economizers, consisting of tubes placed in the path of the waste gases from the boilers, may be installed, and these will still further heat the feed-water; the utmost gain, however, from their use is less than 7 per eent. of the fuel, or, in terms of money, less than $500 per annum, while against this saving must be put about $200, a charge for extra chimney draft, and a considerable sum for keeping it in order and for repairs. I question, therefore, the wisdom of putting in economizers.

A brick chimney of either round or octagonal section, having a central core for a portiou of its height and no firebrick lining anywhere within it, is cheaper and better in the end for fulfilling the purposes of a chimney than either a short stub of a sheet metal stack with forced or induced draft, or than a full-sized steel chimney whether lined with fire-brick or not.

The foregoing remarks are intended to be but brief hints or expressions of opinion in regard to the character of the main elements of a cotton mill power plant, and I will now state rather more in detail the points which it appears to me should obtain in the design of the engine. In what I have said and in what follows, I have reference to a steam plant producing *power* only; for I realize that in the case of print mills, for example, where much hot water and exhaust steam is required, the best arrangement calls for simple engines, economizers and forced draft. My remarks apply to yarn and cloth mills, where but little receiver steam and hot water are needed.

In designing a power plant for a load as steady as the work done in a cotton mill, undoubtedly the most important question to be settled is, What type and make of engine shall be used? All other questions, such as what constitutes the best type of boiler, the best kind of feed-water heater, pumps, etc.,

sink into insignificance in contrast, by reason of the great cost of the engines and the great variety of designs from which to make a choice, either for better or worse in the years to come. For instance, there are large mills to-day which are operated by simple condensing engines, of the slow-speed Corliss type. Again, there are equally large mills operated by four-cylinder, triple-expansion Corliss engines, and also by triple-expansion high-speed engines, working with steam at 160 pounds, and expanding through four cylinders. Here are the two extremes, and one or both must be wrong. Other arrangements of the cylinders which find favor are, (1) the pair compound; (2) the pair of tandem compounds; (3) the tandem triple expansion; (4) the pair of tandem triple-expansion engines; (5) the triple-expansion engine having the first and second cylinders tandem on one crank and the low on the other. Not only are there these seven different arrangements of cylinders to choose from, but any arrangement can be "done" in either high-speed or low-speed, while the number of successful types of automatic engines in the market is large.

As to what particular make of engine will give the best results during a long life, in respect to close regulation, high economy of fuel and repairs, combined with low first cost, I will have little to say, inasmuch as the differences between several types of engines in these matters are slight, being more in the workmanship than the design. Prejudice, too, enters largely into the settlement of this question. There is in reality no functional difference between any of the prominent makes of engine, notwithstanding the wide difference in mechanism and finish. Other things being equal, however, it is natural to select the simplest mechanism for operating the valves, although many do not follow this advice, apparently thinking that in buying something complicated and evidently expensive to build, they are getting more for the money. As to what is the best form of valve for operating under 150 pounds pressure, I confess my choice lies in a direction not much regarded now a

days. I believe the double-beat balanced poppet valve will outlast any other form and still remain tight; and I may say here that the waste of steam through a leaky valve, whether in the cylinder of the engine or in the pipe line, is easily passed over in the running of a plant, and that it may become far more serious than "cylinder condensation" itself. Many a triple-expansion engine is less economical, I believe, than a compound, because of leakage.

The cost of an engine, the cost of repairs, and the cost of manufacturing the steam capable of generating one effective horse power in it, depend more especially upon the arrangement and number of cylinders than upon the make, as the market prices of the different makes are nearly identical. Obviously, the cross-compound, condensing engine, piped so that either side can run alone independently of the other, is the simplest machine both to buy and maintain of any of the seven kinds noted above. As to its steam economy, perhaps it would be well to note its position in the scale of economies of various types of engines.

The single cylinder, non-condensing, four-valve engine uses, under good conditions as to valve-setting and load, about 26 pounds of steam per indicated horse power per hour. The same engine condensing would take 19 pounds, a gain of 27 per cent. This is not pure gain, however, as the feed water must go into the boiler at a lower temperature, *i. e.*, that of the hot-well. The actual gain is but 17 per cent. The compound engine, using steam at a pressure of 120 pounds, will take about 14 pounds, a gain of about 25 per cent. over single cylinder condensing. If the pressure is run up to 150 pounds in the boilers, this engine may do as well as 13½ pounds, though this gain is not sure, and is but 3½ per cent. at best. The triple expansion engine, working under 150 pounds, will give the horse power on a consumption of less than 12 pounds, a gain of 10 per cent. This gain is subject to a discount of perhaps 2 per cent. minimum on account of the friction of the

parts of the extra cylinder, and 8 per cent. may confidently be stated as the difference in favor of the triple engine. The extra cost of the triple engine over the cross compouud is about one-third, or, for an engine of 800 indicated horse power, $6,000, and the value of the coal saved is about $600 per annum. Evidently, if the extra cost for repairs and labor is nothing, the end justifies the means; but the interest is pretty near the dividing line between what is a sufficient amount to justify the extra outlay and what is not, and consequently there may be found to-day engineers who advise the installation of the third cylinder as a good investment, while other engineers think the "game hardly worth the candle," and advise simply the cross-compound. This is, of course, the most popular type of cotton mill engine with practical men.

I have described several arrangements of compound engine, illustrations of which may be seen at work in the cotton mills of New England. I now desire to call your attention to a type of engine not so common or well known as any one of the foregoing, but which I conceive to have merits not possessed entirely by any single one of them, which merits entitle it to be selected as the ideal cotton mill steam engine. That you may the more easily see the reasons why this new type of compound engine is an advance on the other well known kinds, I propose now to consider briefly the theory of the compound engine.

Not to be too elementary, we all know that in the most economical engine — that is, in one having non-condensing cylinder surfaces and frictionless parts — the economic effect is the result of the combined influence of two conditions: using a volume of steam at the highest possible pressure, expanded the utmost number of times. In the actual engine condensation comes in to nullify this abstract truth, and if the theory is to be realized in practice, condensation must be reduced or else its effects must be avoided. This last is what the compound engine actually does. A certain proportion of the steam entering the high-pressure cylinder is condensed instantly by the

cold cylinder walls. The end of the stroke is reached, and what happens? Does this condensed steam leave the cylinder as water? It is well known that it must leave it as steam, and the full bulk or weight of the steam as it originally came from the boilers — minus a certain small amount liquified in doing the work in the first cylinder — passes over into the second cylinder, where some of the entering steam is again immediately condensed.

It is evident that if each cylinder does one-half of the total work, the most economical use of steam will result only when each cylinder causes an equal amount of condensation, because of the fact that if one cylinder condenses less than this amount the next cylinder — or the preceding one — must condense more, and the most wasteful of the two cylinders causes all the loss. Now, when a given weight of steam is passing through an engine in a given time, the total amount of condensation in both cylinders and also the relative amounts of this total occurring in either of the cylinders, depend upon the size of the low pressure cylinder, the relative volume of the high pressure cylinder, the point of cut-off in the low, and the size of the intermediate receiver. It is unnecessary for our purpose to know the precise quantities of condensation in any given compound engine. Let us premise two general facts: (1) With a boiler pressure of 90 pounds and a ratio of cylinder volumes of 1 to 3.5, an equal amount of steam will be condensed in each cylinder of a compound engine, and (2) the size of the engine is so adjusted to the load as to cause this absolute amount of condensation — the same in each cylinder — to be a minimum quantity. It is then evident that no compound engine could be designed to use a less amount of steam per indicated horse power per hour with a boiler pressure of 90 pounds. Why, then, should it be urged — as it is in some quarters — that the same cylinders will give a proportionate increase in economy if the boiler pressure is raised from 90 pounds to 150 pounds, the engine doing in each case the same amount of work? It is

true enough the number of expansions will be increased; but the great increase in temperature range in each cylinder, consequent upon the use of a higher steam pressure, is certain to increase largely the absolute amount of condensation in each cylinder, and thus to reduce the theoretic gain due to an increased number of expansions. This fact, which seems perfectly obvious, has also been demonstrated in a series of careful tests of Corliss compound engines of the largest size. In other words, no gain worth mentioning follows the use of steam of a very high pressure in the ordinary compound engine.

We can now see why it is that the triple expansion engine has any economic advantage over the compound; for it is plain that by the use of three cylinders in series the range in temperature in any one is much less than it must be in either cylinder of the compound, and therefore the *condensation* in any one cylinder is less in the triple than in the compound. The addition of an extra cylinder, however, is, as I have shown, an expense but barely warranted by the gain in lessened coal consumption.

It is natural to ask, Is there no other way of reducing the condensation in either cylinder of the compound — using steam at a pressure of 150 pounds — than by the addition of a third cylinder? I think I may answer that it has been proven, both theoretically and experimentally, there is a much less expensive way, and I now may present for your consideration the merits of the new type of compound engine to which I have referred above.

Let us keep in mind the fact that what we aim at is not, primarily, to reduce the range in temperature, but the initial condensation in either of the cylinders of a compound engine.

These two matters are often confused, as though one was the direct consequence of the other. The absolute quantity of cylinder condensation is caused not only by cold cylinder walls, but also by the extent of the surface of these walls. That is, the greater the surface exposed to a given range in temperature, the

larger is the amount of condensation. In the new system of compounding, therefore, the advantage is urged of reducing the piston area of the high pressure cylinder as the boiler pressure is raised, thus keeping the point of cut-off in this cylinder—and, indeed, in the low pressure cylinder also—always practically the same, regardless of the rise in the boiler pressure. This method of design thus carries out the idea of increasing the number of expansions without at the same time adding to the cylinder condensation, for it reduces the weight of metal in the high pressure cylinder, to be heated and cooled each stroke, without losing any of the thermodynamic advantages peculiar to increasing the number of expansions.

It is, however, important to preserve the conditions as to steam temperature and pressure under which the low pressure cylinder of a triple engine works, the same in the low pressure cylinder of the new type of compound engine, and to this end a large receiver is necessary.

I may say that I was convinced of the truth of the theory, which we have thus briefly glanced at, a good while before the opportunity arrived for me to put it to the test. But whether the theory is correct or not, the fact is that engines working under a pressure of 150 pounds and designed with a high pressure cylinder, reduced below what has been a standard size for engines working with 100 pounds, have uniformly given an economy of steam consumption heretofore undreamed of in connection with anything but a triple expansion engine. Three such engines, one a tandem compound of 700 horse power, and the others cross compounds (of 500 and 600 horse powers respectively) have been tested each by an independent engineer—namely, Prof. George T. Alden, and Messrs. George H. Barrus and F. W. Dean—and in each case the steam consumption has been under 13 pounds per indicated horse power, and might have been considerably lower had all the conditions as to vacuum, jackets, etc., been the best.

So far as I have had experience with the jacketing of cylin-

ders — both high and low — of a compound engine, I may say that the entire gain due to their use does not exceed 3 per cent. I therefore do not advise jacketing the barrel of either cylinder. It is of material advantage, however, to jacket the heads of the low pressure cylinder, and to introduce a live steam radiator of brass tubes into the body of the receiver, allowing at one-half a square foot of radiating surface to the horse power.

Although these notes on the Ideal Cotton Mill Steam Plant form but a fragmentary treatment of the subject, yet I have already devoted so much space to its "Design" as to leave little time in which to dwell on its "Management."

Opinions will, of course, always differ in the matter of what amount of money constitues a proper compensation to the firemen and engine-men, and I will merely point out the danger of making the compensation too small.

Also, the measure of the value of a man's services is by no means his "professional" ability to fire or run his engines; but rather it is the degree of faithfulness with which he does his duties, the certainty and regularity of his attention to the details of operation of the entire plant. One good man, well paid, is usually worth more than two poorly paid men. A general observation of many plants convinces me that the engine-man has far too little to do himself; or, if all his time is fully employed, it is not in work about the steam plant, but probably in some remote part of the mill, piping, or doing menial work of some kind. It seems to me a daily report from the engineer to the office regarding the coal consumption, the evaporation, the speed of the engine, reasons for and times of shut-downs, daily observation of the indicated horse power of the engines, etc., would supply data of much value to the mill agent.

Finally, allow me to point out the advantages of supplying in the engine and boiler house those conveniences, amenities and nice finish; the advantage of requiring that not only the engine room, but the boiler room, the basements, pump houses,

etc., be originally planned sufficiently high, studded to give light and air and space about all machinery, and that all things be "kept up" to the original neatness and completeness. These things, in the whole, have a large money value which cannot be directly measured, but which is none the less real.

Mr. A. F. KNIGHT. Mr. President, I would like to ask Mr. ROCKWOOD if the open type of heater to which he refers can be used to return the heat of the exhaust steam back to the boilers without the danger of having cylinder oil mix with the feed water, and thus be carried into the boiler and collect on the sheets exposed to the fire? Now, we all know that engines are in use which take steam at a boiler pressure of 100 or 110 lbs. pressure and exhaust it through an oil separator and then an open heater, and these heaters give no trouble because the oil is not materially affected in passing through the steam, and is therefore easily separated from the exhaust steam before that is used in the open heater. But some of us also know that when you increase the boiler pressure to 150 or 175 lbs., the greater heat of the steam makes an emulsion of the oil and water of condensation, and this emulsion will appear in the heater. I have never been able to separate the emulsion from the exhaust steam with any separator or arrangement that I have been able to find or that I am at the present time using, although I should be very glad to use any. What I want to inquire is whether it is possible to use the open heater where the boiler pressure is, say, 160 lbs., and still avoid all difficulty from oil?

Mr. GEORGE I. ROCKWOOD. I think Mr. KNIGHT'S point is well taken. Many types of separators on the market — separators which are entirely successful when used in the supply pipe to take out the water of condensation and moisture in the steam, and which are also successful in extracting waste cylinder oil

from exhaust steam in cases where the boiler pressure is not very high — are able to remove this *emulsion* from the exhaust steam. For my part, I am inclined to think that the centrifugal principle is not efficient in separating oil after it becomes emultionized. It is necessary to bring the exhaust steam upstanding by means of baffle plates provided with gutters, to arrest the emulsion and conduct it out of the path of the steam. I have put such separators in plants operating with a boiler pressure of 150 lbs., and there is no trace of oil in the heater.

Of course, there is no positive need of pumping oil into the boiler even though it be present in the heater, as it may be easily and cheaply filtered out by passing the feed through a mechanical filter, as is the rule aboard ship. Over 200 tons of feed-water has to be thus filtered every hour on the *Campania* and *Lucania*, Cunard steamers. It is not a serious matter to filter feed water, if necessary (which, on land, I doubt if it ever is), but it is, on the other hand, a great advantage to use the Webster heater in connection with the receiver of a compound engine, as is done nowadays very widely afloat (in principle, at least, as the Weir form of heater is there used), the Cunard steamers being again instances of this practice; and the *rationale* of the system may be briefly stated thus: The quantity of steam condensed by the feed water represents an amount of steam which has been worked in a theoretically perfect engine, because after doing work in the engine the whole remaining heat, both latent and specific, is returned to the boiler.

Mr. A. F. KNIGHT. How long will hot water meters register correctly the amount of the feed water?

Mr. GEORGE I. ROCKWOOD. I have a Worthington meter in daily use. It hasn't given me any trouble so far. I know it is said that hot water is harder on a meter than cold water, but with very little attention and pure feed water, I think it a good plan to have a motor in use. I am able, from observation of a meter, to tell the evaporation per pound of coal during a long period of operation, and the advantage is that if the rate of

evaporation changes due to poor firing, overloading, or leakage, the meter is likely to show up the fact.

Mr. A. F. KNIGHT. I notice you recommend the horizontal type of engine, while Mr. RICE recommends vertical engines for cotton mills. I would like to inquire the reasons on which you base your opinion?

Mr. GEORGE I. ROCKWOOD. Now, I was careful not to emphasize very much the opinion which I did express in favor of verticals. To defend my prejudice, however, I will say that the horizontal type seems to me better because it is apt to be easier to keep in good order, to oil, and to repair. In a textile mill floor space is comparatively cheap in most cases, so that considerations of economy of ground would not have much weight, while the building suitable for a vertical engine is likely to be more expensive. There is but one advantage peculiar to the vertical type: its pistons do not bear on the cylinders. The extent of the advantage is extremely slight, if the piston of the horizontal is made sufficiently broad and light. It must be kept in mind that we are not now discussing the most suitable kind of engine for steamships or for municipal electrical stations, as I admit that in these places the upright engine is better.

The PRESIDENT. The next paper is, "A Steam Creed," by Captain CHARLES H. MANNING, U. S. N., Manchester, N. H.

A STEAM CREED.

CAPT. CHARLES H. MANNING, U. S. N., MANCHESTER, N. H.

Many of the papers written for this Association have left me so completely in the dark as to the author's belief on the subject of which he was writing, that I made up my mind what little I had to say to-day on the subject of steam, should be put in such form as to leave no doubt of my belief on the few points I shall mention.

First of all, I believe in high steam pressure, and that as our material and workmanship improve much higher pressures will be used than are now in vogue.

Thirteen years since, when the Amoskeag steam plant was reorganized, it was on the basis of one hundred pounds gauge pressure, though the ordinary mill practice then stood at about eighty pounds and my only regret now is that it was not put at one hundred and fifty pounds.

The economy of high pressure turns on the fact that the cost of making steam from feed water is in the change of condition from that of a liquid to a vapor, during which process a large amount of heat becomes latent and when once in the form of vapor a small amount of heat increases the pressure rapidly.

A pound of feed water at 100 degrees F. requires eleven hundred and seven (1107) heat units to convert it into steam of one hundred pounds gauge pressure, whereas the addition of but seven more heat units will increase the pressure to one hundred and fifty. Practically, the difference in cost is slightly greater than this, as at the less difference of temperature of the steam and the gasses of combustion the efficiency of the heating surfaces is less.

The next most important feature is that the steam shall be

dry, and to make sure of this a small amount of superheating is advisable, and the greater distance the steam is to be carried, the greater this superheat should be, though on account of cylinder lubrication it should not reach the cylinder at a temperature of more than thirty to forty degrees above that due to its pressure, in horizontal engines; though with vertical cylinders, where lubrication is much easier, a higher temperature is admissable and desirable and, I believe, in superheated steam.

To obtain this high pressure superheated steam at a minimum cost, there is no question that a vertical fire tubular boiler with tubes extending through the steam space is superior to any other. Such boilers have a limited volume of steam space but this space has considerable heighth, which feature has more to do with the dryness of the steam than has the volume, and the degree of superheating is easily controlled by varying the water level.

With the increased pressures of to-day, the horizontal tubular externally fired boiler, so commonly used for the last thirty years, must disappear, as a shell of greater thickness than half an inch, exposed directly to the fire, is inadmissable and this limits the shell diameter to less than is desirable. In the vertical boiler the shell is not limited in thickness, as it is not subjected to the deteriorating influences of the fire, nor to the distortion that the horizontal shell is, and therefore it has a longer lease of life and can be made of any desired diameter for any reasonable pressure.

The fire-box sheet does not have to be increased in thickness with increase of pressure, being a stayed surface, as the spacing of the stays can be regulated to the pressure it is desired to build for. Vertical boilers, with a straight rigid shell, always give trouble from the difference of expansion between tubes and shell, but with this difference of expansion taken care of, the tubes will last as long as in any other form of boiler.

There are many water tube boilers on the market capable of carrying high pressures, but most of these make very wet steam, which is not only dangerous to cylinder heads but also very hard

on the coal pile. In one case I have in mind, the *moisture* in the steam when a sudden call for power was made amounted to 50 per cent. The first cost, the cost of repairs and the space occupied by this type of boiler are all large. For these and many other reasons, I believe in a vertical fire tube boiler.

For an engine in which to use this steam, there are many points to be considered and the first is as to what use besides power is to be made of the steam. If these other uses are such that all the exhaust steam of a simple engine of the required power, using one hundred pounds initial pressure and exhausting against the required back pressure, can be utilized, then the simple non-condensing engine is the best. Should this arrangement show a surplus of exhaust, the next type to be considered should be a compound, with one hundred and fifty pounds initial pressure, the second cylinder in this case exhausting against the required back pressure. Should this arrangement show a surplus of exhaust, the next type to be considered would be the compound condensing, with cylinders so proportioned as to allow the required amount of low pressure steam to be taken from the receiver at the desired pressure, to do the dyeing, drying or heating, as the case may be. For my belief in the economy of the use of back pressure steam I refer you to remarks on a former occasion.

I do not believe there is much economy in compounding an engine for pressure of much less than one hundred pounds per gauge, nor in using three cylinder expansion engines for less than one hundred and fifty pounds gauge pressure, but I do believe that with pressures of one hundred and fifty pounds and over, better results mechanically and economically can be obtained with three cylinder expansion than with two.

With increased number of cylinders the trouble of close regulation with variable loads increases considerably, as the regulation must be done on the first cylinder, for the steam once admitted to that cylinder must pass through them all and cutting it off earlier in the other is only putting off the evil day,

I believe in steam jacketing all but the low pressure cylinder with boiler pressure steam and I do not believe in passing the steam through the jacket to the cylinder as some builders practice, as I have found that a large part of the jacket condensation is carried along into the cylinder where it is harmful. I believe in finishing the entire interior of cylinders and the exterior of pistons, both to reduce clearance and cylinder condensation.

I am a firm believer in the vertical engine, more especially for high powers involving large cylinder diameter. With a vertical engine the scoring of cylinders which we hear so much of in large horizontal engines is almost unknown and certainly unnecessary.

A large piston lying on its side and dragged back and forth at the rate of seven or eight hundred feet a minute on a hot surface is no easy affair to keep lubricated.

This type takes much less floor space and is very much easier to take care of and when our shops get used to building them, as they will have to, I believe they can be built for as small a cost as the horizontal.

I believe in independent condensers and where a head of water is available I think the gravity system the best.

Finally, I believe that very many of you differ with me on many points, but we cannot all expect to join the same church.

Mr. F. M. MESSENGER. I do not share in the opinion that the horizontal tubular boiler has become a thing of the past. I believe that under certain conditions the vertical boiler is best, but where feed water is bad I understand it gives trouble. I know of one put in by a party and its use discontinued in less than one year; owing to the conditions of the feed water it took a gang of men every Sunday cleaning it out.

I believe for high pressure the Manning boiler is best, although if built right, and properly designed for its work, the horizontal tubular boiler is all right, both as regards safety and durability,

for this class of work. We have at our place three horizontal boilers which have been run at high pressure for two years; they are doing good work and stand the test well. If we extend our plant, which we expect to do, we shall match up and put in the horizontal tubular boilers. If I were to start new, it is my opinion that I should put in the vertical boiler if water and conditions were favorable to it; but I would not strain a point to adopt it as I still consider the horizontal tubular boiler in the field.

Captain CHARLES H. MANNING. The matter of using impure water is a vital mistake. If water isn't fit for a vertical boiler, it is not fit to be used in a horizontal boiler. More accidents have occurred to horizontal boilers than ever occurred to vertical boilers. The boilers at the Amoskeag Mills, having been in use thirteen years, and they are just as sound as the day they were put in, and as far as I can see are good for another thirteen. Anybody that would throw a boiler away because he is using dirty water, I think is using poor judgment.

Mr. A. F. KNIGHT. I would like to ask Mr. ROCKWOOD one question in regard to lubrication, one that was presented to me. Can graphite be used for a lubricator instead of cylinder oil?

Mr. GEORGE I. ROCKWOOD. I have not as yet used graphite instead of oil; but I have confidence in it as the better means of lubrication for cylinders in which steam is used of a temperature hot enough to change the nature of ordinary cylinder oils.

The PRESIDENT. The next paper to be considered is "Water Power, Its Development," by Col. SAMUEL WEBBER, of Charlestown, N. H., read by the Secretary.

WATER POWER AND ITS DEVELOPMENT, AS CONNECTED WITH THE COTTON MANUFACTURE.

COL. SAMUEL WEBBER, C. E., CHARLESTOWN, N. H.

The Board of Government have invited me to prepare a paper on the subject named in the above heading, to be presented to you to-day, and in so doing, it seems pertinent to remark that water power was the foundation of the great cotton manufacturing industry, both in the Old World and the New. The writer, when in England in 1851, saw the little mill at Belper, in Derbyshire, in which Arkwright started his first spinning frames by water power, and the name of "Watertwist," long held in England, as applied to the smooth, hard, twisted yarns spun on the throstle, to distinguish them from the softer yarns spun by hand on the old "Jenny."

Although the water powers of England were small and few, they have long since been nearly all occupied, and are held at high rates; while so many of them have been utilized for grain and paper mills, that the cotton manufacture was soon compelled to use steam, the principal source of power in England.

In fact, the steam engine and the cotton mills grew up together in England, and it is to the continent of Europe and the United States, that we must look for the development of water power. Water was put at work in New England at a very early date, as will be seen by the accompanying copy of the first patent granted in the New World, on the 6th of March, 1646, by the General Court of Massachusetts, to Joseph Jenkes, Sup-

erintendent of the Saugus Iron Works at Lynn, and for which I am indebted to your Secretary, Mr. Woodbury.

"JENKES MONOPOLYE."

"AT A GENERALL CORTE AT BOSTON.

"The 6th of the 3th mo., 1646.

"The Corte consideringe ye necessity of raising such manifactures of engins of mils to go by water for speedy dispatch of much work with few hands, and being sufficiently informed of ye abilities of ye petitioner to pforme such workes, grant his petition (yt no other person shall set up, or use any such new invention or trade for fourteen years, without ye licence of him, ye said Joseph Jenkes), so farr as concerns any such new invention and so as it shalbe alwayes in ye power of this Corte to restrain ye exportation of such manifactures and ye prizes of them to moderation if occasion so require."

We find water applied to the manufacture of cotton by Samuel Slater, at Pawtucket Falls, in 1790. The Passaic River at Paterson, N. J., seems to have been the next water made available for cotton spinning, but the small powers all over New England and into New York and Pennsylvania, were rapidly taken up, until in 1821, we come to the bold step of employing the Merrimac River, at Pawtucket Falls, in Chelmsford, now Lowell. Fall River, or the "Quequechan," was, however, utilized by the Troy Manufacturing Company in 1813, and has long since outgrown the water.

The original suggestion of the use of the Merrimac River is due to Mr. Ezra Worthen of Salisbury, by whom it was made to Mr. Paul Moody of Waltham, and by him to Messrs. Nathan Appleton and Patrick T. Jackson, who, satisfied with the success of the mill at Waltham, were looking out for an opportunity to manufacture cotton on a larger scale. Messrs. Worthen and Moody were both engaged in the formation of Lowell, one as agent of the first mills, the "Merrimac," the other of the machine shop.

A canal, with "locks," had been built around Pawtucket Falls,

for the purpose of navigation, and it was this canal that Mr. Worthen purposed to make available. As orginally planned, it left the Merrimac above the falls, came on the present line to the "Swamp Locks," near the Lowell Machine Shop, where there was a drop of 13 feet, and then followed its present line to the lower locks, back of the American House, where with a drop of 17 feet, it was discharged into the Concord River.

This, for the old style of breast-wheels, was very satisfactory, and was employed in the development of the power, by cutting a canal from the basin above the "Swamp Locks," northerly to the river, taking water from it for the machine shop, and the mills of the carpet or "Lowell Company," and discharging it into the old canal below the locks, with 13 feet fall. This canal however, reached the river on a high enough level to enable the Merrimac Mills to use the whole fall of 30 feet to advantage, Mr. Moody being in favor of large wheels.

Another canal was cut on the south side of the old one, below the locks, using the same fall of 13 feet, on which the Hamilton and Appleton Mills were built in 1828, the latter being believed to be the first mill to use main belts of leather instead of shafting.

The lower or old canal was extended around the angle formed by the junction of the Concord and Merrimac Rivers, until it reached the Merrimnc canal, which, by an overflow, discharged its surplus water into it at that point, and also drove a small grist-mill.

On this lower level, at a later date, were built the Boott and Massachusetts Mills, with a fall of 17 feet.

Another canal was carried to the northwest, from the "Swamp Locks" basin, and turning to the north, parallel to the Merrimac canal, reached a "bench" or terrace, when the first fall of 13 feet was used for the Tremont and Suffolk Mills, now united.

From these mills the water was discharged into a lower level canal, which supplied the Lawrence Manufacturing Company with 17 feet fall. Of these mills, the Merrimac Company and the

Locks and Canals Company Machine Shop, were begun in 1822, the Hamilton Company in 1825, the Appleton and Lowell in 1828, the Suffolk and Tremont in 1830, the Lawrence in 1831, and the Middlesex Mill, on Concord River, in 1830, the Boott Mills in 1835, and the Massachusetts in 1839. The latter mills were just in operation, when the writer came to Lowell in 1841, and were all driven by the old-fashioned breast-wheels.

In 1844, the first turbine was put in at the Appleton Mills, and in 1845–6, the Prescott Mills, afterwards purchased by the Massachusetts, were built and operated by turbines.

Although these matters may be familiar to many of you, I recapitulate them as having a bearing on the apparently excessive cost of the water power at Lowell. The writer saw the first turbine started in Lowell, and assisted in the drawings for the last large breast-wheels put in on the Merrimac River, at the Bay State Mills in Lawrence in 1848. The Prescott Mills practically exhausted the water power, as obtainable by the original canals, and it was deemed advisable to build the northern canal on the river banks, in 1847–8.

Meanwhile, the other water powers in New England had been rapidly taken up, from the Saco River in Maine, the Salmon Falls, Cocheco, Sowhegan, Nashua, and the Merrimac at Amoskeag Falls in New Hampshire; Fall River, the Taunton River, the Blackstone, the Chicopee, the Quinebaug, and the Housatonic in Massachusetts, Rhode Island and Connecticut; to the Mohawk at Cohoes, and the Passaic at Paterson, with many minor streams and tributaries which had all been set at work spinning cotton, and it was not until 1830, that the first steam mill was started at Providence, R. I.

To return to the water power of Lowell, Mr. NATHAN APPLETON, in his pamphlet on the "Origin of Lowell," says it was originally estimated at about 9,000 horse power, and this was divided into 139 "*mill powers*," of about 60 horse power each, or the power produced by 25 cubic feet of water per second on 30-foot fall, on which basis the Merrimac Company, in the final allotment in 1853, received $24\frac{28}{60}$ mill powers. On the 13-foot

fall the mill power was designated as 60½ cubic feet per second, and on the 17-foot fall as 45½ cubic feet per second, and on these terms the original 139 mill powers were divided in 1853.

The expenditure in 1823 for the first 50 mill power was stated by Mr. APPLETON as $120,000. This included the purchase and enlargement of the old canal, and a large amount of land, and was equivalent to $40.00 per horse power. I have no record of the farther cost up to the date of the new or northern canal in 1848, which was $530,000, but which materially increased the power by raising the head on the upper level from 13 to 14 feet, while deepening the channel of the river below has increased that on the lower level from 17 to 19 feet, so that the total cost per horse power, usually stated at $200.00, is much less if taken on the 23,000 horse power of turbines, which the "Lowell Year Book" of 1889 states to be in the mills. Some of them, however, were on the Concord river, perhaps 2,000 horse power.

I have given these facts because I have often heard it said that Lowell would not have been built to-day to be driven by water power.

My answer to this is, that the improvements in the appliances for water power have been as great as those in the steam engine, and that the water power of Lowell could be developed to-day for less than one-half what it has cost, and in support of my statement present the following data, beginning with the last development on the Merrimac river, at "Sewall's Falls," 22 feet. Here 700 acres of land were purchased, a dam built, canal dug, and some wheels put in pits, and the cost is given me as follows:

Land and flowage rights,	$20,000 00
Dam,	141,015 17
Canal,	27,362 98
Head Gates,	16,675 00
Wasteweir,	5,220 10
	$210,273 25

Average H. P., on 22-foot fall, 5,000 = $42.05 per H. P.
Minimum H. P., on 22-foot fall, 3,300 = $63.72 per H. P.

Now to either of these add,

Wheel pits and foundations for 2,000 H. P., $15,000, or	$7.50 per H. P.
Turbines for 16,000 H. P., $12.225, or	7.66 "
	$15.16

and we have respectively a total investment

For the minimum H. P. of $78.88
" average H. P. of $57.21

and allowing on these sums 5 per cent. interest, 2½ per cent. sinking fund, 1½ per cent. repairs, and 1 per cent. taxes and insurance, we have 10 per cent. as the annual cost, with 75 cents per horse power attendance and oil; we have $8.64 or $6.47 respectively as the cost of a horse power at the dam in Concord. In making this allowance for sinking fund at 2½ per cent. I estimate it at 1 per cent. on the wheel pits and foundations, and 4 per cent. on the wheels and other iron work. If, as in the case of the John P. King Mill, these items are equal, the average would be 2½ per cent. In the case of the other southern mill quoted, and the Sewall's Falls plant, the average would really be less than allowed, and the insurance on such property should be merely nominal. I am not familiar enough with the expense of electric transmission to say what it will cost in the city.

There are, however, few available water powers left in New England, and it is not probable that any of them will ever be employed for cotton manufacture, which is drifting to the South ern States, where there are ample powers near the cotton fields, and from this section, I get from Mr. CHARLES ESTES, the following facts, in relation to the John P. King Mills:

Head Race, 200 feet long, 40 feet wide.
Tail Race, 800 feet long, 26 feet wide.
Wheel Pits, 42 feet deep, nearly all rock excavation.

Total cost of above,	$25,000 00
Wheels and Jack Shafts,	25,000 00
Or for 1,835½ gross H. P.,	$50,000 00
This would be=$27.25 per H. P., on which 10 per cent.=	$2 72
Water Rent, City of Augusta, per gross H. P.,	5 50
Making,	$8 22
Now I tested these wheels, which gave 84 per cent., but allowing them to net only 80 per cent., it gives,	$10 30
To which add for attendance and oil,	75
We have for the total cost at Augusta,	$11 05

And Mr. ESTES writes me that the city of Augusta has leased 10,000 horse power on the same term.

It would certainly be difficult to produce steam power at above rates, unless in a coal mine.

These figures of cost, are confirmed by the following data, received from another southern water power with 27-foot fall:

Cost of Wheels for 2,000 H. P., = $20,000	$10.00 per H. P.
" Pits, Feeders, Tail Races, Wheelhouse, etc., = $55,000,	27.50 "
	$37.50

Cost exceptionally heavy from striking bad soil and quicksands,

Annual expenses, at 10 per cent. on $37.50,	$3.75
Water Rent, $7.00 per H. P., for less than 500 H. P., *over* that,	5.00
	$8.75
Add for attendance, oil, etc., including attendance on electric dynamos,	1.00
Total cost for H. P.,	$9.75

These data show what water power can be furnished for to-day, under favorable circumstances.

One great item in the cost of the water power at Lowell and other northern cities, has been the underestimate of the projectors, as to the amount of water which *could* be used at certain seasons, and the insufficiency of the waterway provided. Both at Lowell and Manchester the canals were far too narrow, and the loss of head too great.

Even at Lawrence, laid out on a more comprehensive scale, the velocity of the water in the northern canal has been such as to undermine the canal walls in places several times.

The velocity of the water in these early canals has been 5 or 6 feet per second, when it should not have been over 3. The first canal at Lowell was only 60 feet wide by 8 feet deep, or 480 square feet, and while this would have answered very well for the first 50 mill powers, or 1,200 cubic feet of water per second, it was entirely insufficient for the subsequent increase.

At Manchester, there was a loss of 1 ft. head in the upper canal, and as it was impossible to widen that without rebuilding the Concord railroad on an iron viaduct, the new dam built in 1871 was raised a foot. This dam built in the most perfect manner, with dressed stone and cement, cost $60,000. or at the rate of $6.00 per horse power for the 10,000 horse power which it furnishes.

While I do not intend to enter into any discussion of the relative merits of steam and water power, both of which have their advantages for certain purposes, and under certain circumstances, and which still seems to be as open a question as it was fifty years ago, when Gen. Charles T. James of Providence, proposed to eclipse Lowell and Manchester, by steam mills, at Salem, Rockport, Newburyport and Portsmouth; I can say that the gentlemen who speak of the great cost of water power, forget one thing, and that is that the first cost has been largely reimbursed to the projectors by the sales of land in the cities that have grown up around the mills. The land sales have been a

constant source of revenue to the Amoskeag Co. The Essex Co. have returned half the capital to their stockholders, and it is some years since the mills at Lowell, which own the old rights of the Locks & Canals Co., have paid any water rent on the original leases, the whole expenses having been met by the payments for surplus water, and rents of land and other property, if I am correctly informed.

The great cause of the complaints made about water power, has been overloading the natural flow of the streams, and this has been intensified by the clearing of the forests around their headwaters.

Had the mills on the Merrimac river confined themselves to their original plans, we should hear no complaints of short water and the expense of running "double plants." It has been over-taxing the rivers, which has called in steam to fill up the deficiency. As I have said, I expect to see no more waterfalls utilized for the manufacture of cotton at the North, but the two old friends and allies will transfer their field of co-operation to the Southern states, where the rivers are more equable in their flow, and the cotton grows handy to the mill doors.

There are a few unused water powers left at the North, some of which, by means of electricity, may be made to assist the mills now in operation, but I look to the seashore of southern Massachusetts and Rhode Island, where the climate is modified by the gulf stream, for the future development of the manufacture of fine fabrics, by steam power, which must now be used for future mills, and which can be got much cheaper in such locations than if the coal had to be carried miles inland by railway.

The remaining water powers of New England will be all needed for other purposes, and electrical transmission will easily develope the more inaccessible ones.

To those of you, and I have no doubt there are many, who within a few years may become interested in cotton mills at the South, let me offer the following suggestions. Ascertain the

minimum flow of the stream you propose to use. Then if you can store the night flow in your pond, you can calculate on double that quantity of water for daily use without interruption. If you can get the drainage area and the average rainfall, you can calculate on 1/6 of that as the minimum flow, or 1/3 if you can store at night.

It may be advantageous to note that from the drainage area above Lowell, 4,000 square miles, with an average annual rainfall of 42 inches, Mr. Francis noted a minimum flow of 30 cubic feet per minute, per mile, an average or "June flow" as he said, of 55 cubic feet per minute and a maximum of 90 cubic feet, and the turbines at Lowell have been put in to use this maximum.

It is also curious to note the comparative equality of the three great powers on the Merrimac river. Manchester, with 49 foot fall and 2,790 square miles drainage area; Lowell, 33½ foot fall and 4,000 square miles, and Lawrence, 28 foot fall and 4,600 square miles, each furnishing practically 10,000 horse power.

Allow ample water-ways, make your canals large enough to require a velocity of water of not over three feet per second, and your feeder pipes to the turbines of not over 2½ feet, tail races the same, thus you will utilize all your head.

If you have sufficient head to put your turbines on horizontal shafts and keep your belts out of water, do so, you will get just as good a result, save the cost and annoyance of bevel gears, and at least 5 per cent. of your power.

Also, if possible, put in pairs of turbines, thrusting against each other, instead of single wheels. They will cost a little more, but you will save friction on bearings. Have the wheels themselves bronze instead of iron, that is also an additional cost, but it is a small percentage of the whole expense. I can refer you to no better examples than the wheels at the Jefferson mills at Manchester, as advised by Mr. Francis, or the pair which I planned myself four years ago for the Nashua Manufg. Co.

The data which I have collected above on the cost of water power only confirms the statement of Mr. Sam'l. Batchelder, in

his little "History of the Cotton Manufacture," that the water power in Lowell, in his day, "did not cost over $15.00 per annum per horse power, including land."

I trust you may find this paper of interest, and as one of the few survivors of those present at your first meeting, and one of the three men who called it, it gives me great pleasure to present it to you, although inability to hear, has long prevented me from attending your meetings.

The PRESIDENT. The next paper is "Water Power Development and Its Cost," by Mr. A. C. RICE, Dayton, Ohio, read by the Secretary.

WATER POWER DEVELOPMENT AND ITS COST.

A. C. RICE, DAYTON, OHIO.

As there have been so many articles written on the water powers of Holyoke, Lowell, Lawrence, Manchester, and many other places in New England, I have taken an undeveloped power, for which plans and contracts are made, on the Chattahoochee river, at Thornton Shoals, Georgia, on which to base the cost of development as given in this paper.

It is intended to develop 14,000 horse power, under a working head of 35 feet, which will be transmitted electrically to the city of Atlanta, Ga., a distance of about seven and one-half miles. In my estimate I shall only give the cost of the power delivered on the switchboards in the power station, leaving the cost of transmitting the power to the distributing point entirely with the electrical engineers.

Before going into details regarding the power plant I will make some mention of the Chattahoochee river, which is the largest and longest in the state of Georgia, its head waters being in the forest-clad regions of the Blue Ridge mountains in northeast Georgia. The watershed embraces a territory of over 1,400 square miles, abounding in inexhaustible springs, from which source a minimum flow of the stream is derived, supplemented with an abundant rain fall. From data received from the well-known engineers, Hall Brothers of Atlanta, and from state records, I find that the natural flow of the river at minimum low water to be about 150,000 cubic feet per minute, or 7,970 horse power at 80 per cent. efficiency, using 35 feet head, with a storage capacity that will be obtained by building a dam 35 feet high, it will be possible to use 14,000 horse power for 10 hours per day, leaving 4,000 horse power that can be used during the remaining 14 hours.

The dam will have a base of 100 feet running with the steam, and will have a natural flat rock foundation.

The base will be built in the form of a crib in squares of 10 feet, and 10 feet high above low water in river. To a height of about 3 feet above bed rock this crib will be bedded in concrete, then filled with loose stone to a height of 6 feet above concrete.

The front side of the dam is made in two angles before the level apron is reached, which is 10 feet above low water in river, leaving only a sheer fall of 10 feet out of 35 feet total fall. The pond formed by the dam will be about 5 miles long.

At the end of the dam nearest power house there will be 6 waste pipes, 5 feet diameter, provided with wicket gates which can be operated from a platform 8 feet above crest of dam and level with abutment of dam. These waste pipes are intended to take care of the natural flow of the river if there should ever be an occasion, when it will be necessary to draw the water from the pond above dam.

The power house will be 48x323 feet outside, and above foundations will be entirely of steel construction. The founda-

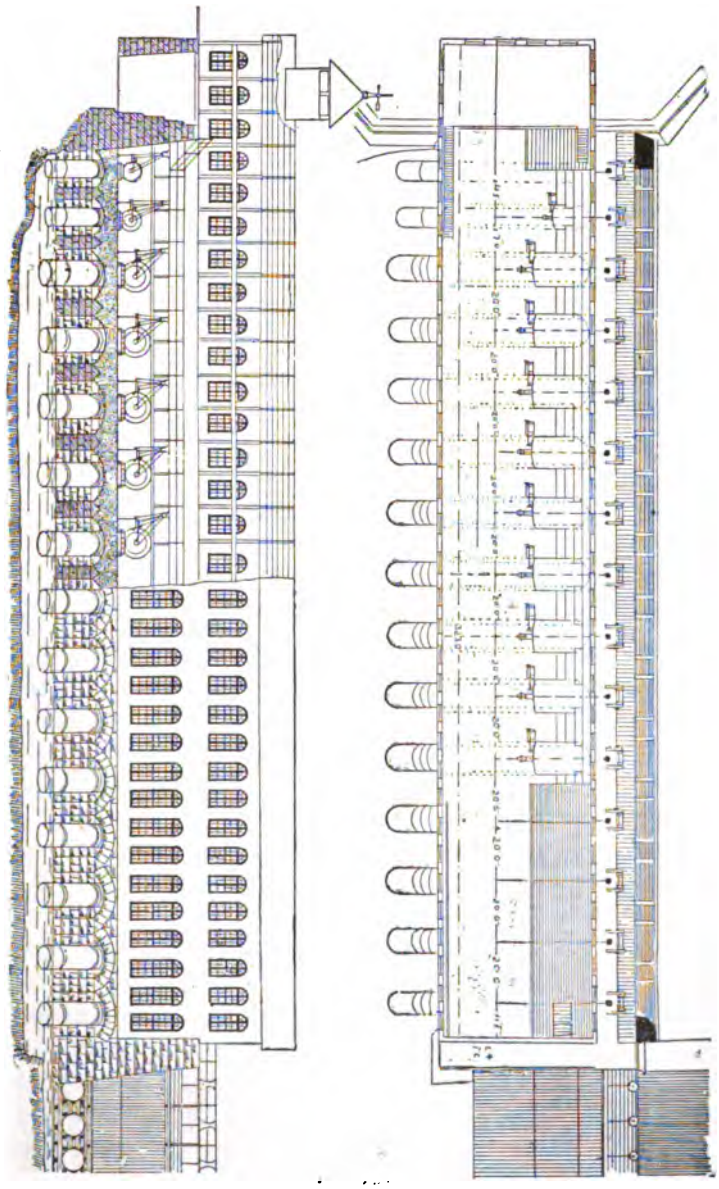


Fig. 2.

Fig. 1.

tions for the upstream side will also be the forebay wall, and the outside foundation will also be part of the abutment for the dam, the balance of the abutment running upstream from power house and forming river end of forebay (see Fig. 1). From the shore end of building starts the forebay wall which extends about 20 feet upstream, from which point a wing wall is thrown into the bank. On the downstream side, the wall forming the side of the tail race, is carried the same distance from building with a wing wall same as on the upstream side. Both of these

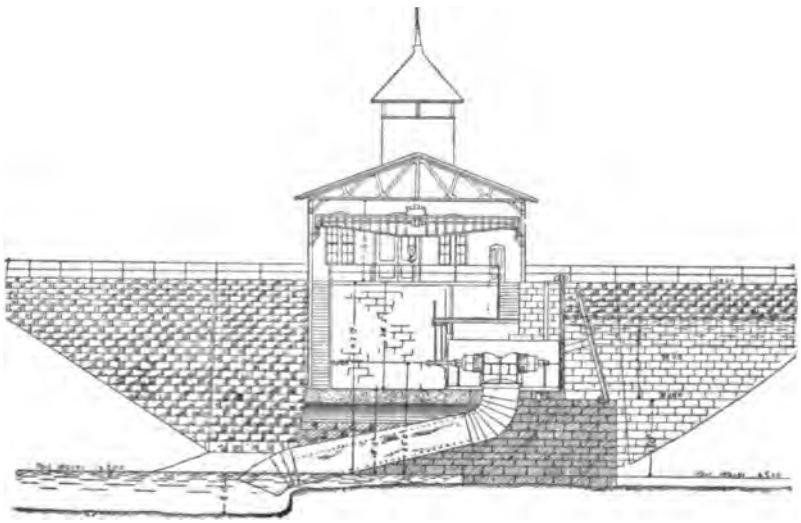


Fig. 3.

walls are 8 feet above head water. The bottom of the forebay to a point about 20 feet from inside of building is 18 feet below head water and from there the bottom of the forebay is the bed rock of the river (see Fig. 2).

The tail race does not extend under the building, but the draft tubes from the turbines are carried under the floor to the lower side of the building and there drop into the tail race which is 8 feet deep. Between these draft tubes are partition walls 4 feet thick, on top of which are turned concrete arches to form the foundation and floor for generator room, which is 18 feet, 9 inches above tail water (see Fig. 3).

The total height of the building from tail water to the bottom of roof trusses is 61 feet. The building is provided with a 20-ton travelling crane which travels the entire length.

The power plant is divided into 13 units of 1,000 horse power each, and 2 units of 500 horse power each. The turbines are of the horizontal type, arranged in pairs, discharging the water into one draft tube and are set in steel flumes, which are built into the forebay wall at the upstream end, while the part of the flumes which extend inside of building are supported on steel (I) beams resting on the partition walls. Out of the down-stream end of the flumes the turbine shafts will extend with a coupling which will connect direct with the shaft of the generators. Each pair of turbines will be supplied with a combination mechanical and electrical governor to insure perfect regulation of speed under any changes in load that may take place. Over the end of each flume there is a head gate to shut the water out in case of accident to the turbines. In front of head gates is an iron water rack 27 feet high and supported by a frame-work of steel channel beams. The water rack extends across forebay a distance of 300 feet.

The entire cost of the plant as above described and which is intended to be a model in all its details, will not exceed $46 per horse power, delivered on the switchboards in the power house, or a total cost of $644,000, including water power and real estate.

The operating expenses per year would be approximately as follows:

Interest on investment at six per cent.,	$38,640 00
Insurance and Taxes at one per cent.,	6,440 00
Depreciation,	5,000 00
Two men at $2,000 each,	4,000 00
Four men at $1,000 each,	4,000 00
Oil and waste,	300 00
Incidentals,	500 00
	$58,880 00

This would show an average cost of $4.20 per horse power per year.

I have plans completed for the development of several other large powers, and will give approximate cost and operating expenses in way of comparison with that of the Chattahooche River power.

It is intended to develop the largest of these powers for 36,000 horse power under a working head of 12 feet. The power will be divided into units of 1,000 horse power each, and will be arranged for electrical transmission. The estimated cost of the entire plant will be $73.97 per horse power delivered on the switchboards in power house, on an investment of $2,663,200 including water power and real estate. The approximate cost of operating this plant per year, on the same basis as the Chattahooche River power, will be $219,224.42, or an average of $6.09 per horse power.

From the other power it is intended to develop 20,000 horse power under 28 feet head in units of about 1,300 horse power each. This power as in the case of the two others will be used for electrical transmission and the estimated cost of this power delivered on the switchboards in the power house is $46.62 per horse power or an investment of $932,500.00 including water power and real estate. The approximate cost of operating per year, calculated on the same basis as the other two powers, will be $81,775.00, or an average of $4.09 per horse power.

I think these comparisons will give an idea of the cost of developing large water powers for electrical transmission with use of the most improved hydraulic and electric machinery, buildings mostly of steel construction, and equipped with all modern labor-saving conveniences, making these plants as economical in operation as modern engineering methods will admit.

EVENING SESSION, APRIL 24, 1895.

The PRESIDENT. The first paper for your consideration this evening is, "Some Thoughts upon the Production of Steam, with Special Reference to the Use of Cheap Fuel," by a miner of coal, Mr. ECKLEY B. COXE, Drifton, Penn.

SOME THOUGHTS UPON THE ECONOMICAL PRODUCTION OF STEAM, WITH SPECIAL REFERENCE TO THE USE OF CHEAP FUEL, BY A MINER OF COAL,

MR. ECKLEY B. COXE, OF DRIFTON, PA.

"Timeo Danaos et dona ferentes."

IT may seem curious that a person whose life has been spent in mining and marketing coal should appear before this association to discuss the economical production of steam, involving as it does, either the use of less fuel or fuel of less value. But I am convinced that the more valuable a ton of coal becomes to our customers, the more in the end will be our profit from it. I have been accustomed to consider the subject from possibly a peculiar point of view. Anthracite coal miners are among the largest consumers of coal for steam. Our collieries, which in 1894 produced, including coal for local use, 1,315,355 tons, consumed 152,661 tons to produce the steam necessary for the works, the most important item being the steam required to pump the water from the mines. Coal miners formerly were accustomed to regard steam as something that cost little or nothing, as no account was taken of the fuel used, which was generally one of the cheaper grades, or coal which could not then be sold. Boilers were erected on the simplest and generally most uneconomical

plan; the only question considered was how to get the maximum amount of steam for a minimum outlay for the plant. The same is true of the engines and pumps used. We only tried to get an engine of a given horse power, or of a supposed or guaranteed horse power for the least money. The firing was generally done with comparatively cheap labor, while little or no attention was paid to the amount of coal burnt, water evaporated per pound of coal, composition of ash, composition of stack gases, or stack temperatures. But of late years, in consequence of extension of the mines, much larger quantities of water have to be pumped from greater depths, coal has to be raised from greater depths, much more steam is required for the machinery now necessary to prepare coal, and for the underground transportation, and in consequence there has been much more attention given to improvements in machinery, boilers, and methods of firing. Some idea of how important this is becoming may be judged from the fact that there are mines which burn 25 per cent. of their production in order to obtain the necessary steam.

Originally brought up to believe that steam cost nothing at the mines, I have gradually had forced upon me the conclusion that it is one of the most important fields for economy in coal mining, and that the direction in which this economy should be sought is in the intelligent use of those products of the mine which are now of little or no commercial value.

I have not approached the subject from the standpoint of the mechanical expert, who is employed to design, improve, or examine steam plants for large and intelligent users of steam, but from the standpoint of a coal miner and coal merchant, and from that of an engineer who has an intelligent interest in all the important problems of his profession.

In the following paper I propose to offer for your consideration some thoughts and the results of some experiments which, although largely commercial, have been conducted more or less on scientific principles. I have considered some small details to be of great importance, but have avoided as far as possible

too much refinement in the discussion. I have given figures and our way of arriving at them, and also my authorities where results are not taken from our own experiments, so that any one especially interested in the subject may be able to check up my work. I have, in some cases, given the results in dollars and cents or in percentages, as, after all, the financial view of the situation is the controlling one. I do not claim to have solved the problem, but simply hope to raise some important issues. Cheap steam is the cornerstone of success in most manufacturing businesses, and there never was a time when those, whose plants are so located that they depend on fuel to obtain power,—particularly if the fuel must be transported a long distance—should give more attention to the subject than now, when there is such a tendency to move manufacturing industries either to coal-producing centres or where coal can be purchased cheaply, or where water power can be obtained and utilized, as is now being done by means of electricity. I use the words "cheap steam" instead of cheap power, for at no time has greater progress been made, or more intelligent thought been devoted to the economical use of steam, than now. It is pretty well demonstrated that the use of the higher pressures in properly-constructed engines, is leading to great economy. This question I do not propose to discuss, as there are many, particularly in this part of the country, far better fitted to do it than I. I do not use the word "cheap" in an absolute, but in a relative sense; that is to say, I refer to the production of steam at the least cost under the conditions in which each manufacturer is placed, and not to the question at what point in the United States can the cheapest steam be produced. For what would be an ideal plant at the mines, where practically waste product costing from 5 to 20 cents a ton can be used, might be a very bad one at a point where two or three dollars had to be paid for transporting the coal from the mines.

To make steam requires three things: Fuel, a furnace, and the boiler, with its accessories such as the economizer or feed-water heater. To make *cheap* steam requires these three and

brains. Eternal vigilance is said to be the price of liberty; it is also the price of cheap steam. I will consider these subjects somewhat in the following order:—

1st. The fuel.

2d. The furnace.

3d. The boiler, about which I shall say little or nothing.

I will try to distribute the brains over the whole paper.

The fuel may be either animal, vegetable, or mineral. The only ones that are of special interest in this connection are anthracite and bituminous coal. There are, of course, in some localities, large quantities of steam produced by mineral oils and natural gas; but I will not devote any attention to the two latter, as they are only of special or local application.

Anthracite coal contains generally from 75 to 90 per cent. fixed carbon, from 2 to 14 per cent. of ash, from 1 to 2 per cent. of water, and from 4 to 8 per cent. of volatile matter. The latter is generally composed of carbon, oxygen, hydrogen, and nitrogen. Bituminous coal contains practically the same substances, except that the proportion of volatile combustible matter is very much greater; so that unless burnt under proper conditions, a good deal of smoke may be given off. The average composition of bituminous coal is about the following: From 1 to 4 per cent. moisture; 4 to 12 per cent. of ash; 15 to 35 per cent. volatile combustible matter, and from 55 to 75 per cent. of fixed carbon. Anthracite coal when it burns does not cake or agglomerate, but remains in the form in which it is placed in the fire, each particle burning from the outside only. Bituminous coal, on the contrary, agglomerates and forms a spongy mass, so that the fine coal does not run through the grate bars, which occurs with anthracite, often causing great loss. Of course, both coals will clinker if the temperature of combustion is sufficient to fuse the ash; and when this occurs a considerable amount of coal is included in the ash, unless special care is taken to prevent it. All coals differ more or less in this respect, and when burnt in the ordinary way, their values may be much affected by the facility with which they clinker.

In calculating the cost of a given quantity of steam, it is necessary to consider, *first*, the interest on the cost and the depreciation of the plant; *second*, repairs; *third*, the cost of water; *fourth*, labor; *fifth*, getting rid of the ashes; and *sixth*, cost of fuel in the boiler house. If one fuel only is available, the plant should be so arranged that with it the maximum number of pounds of steam of the required pressure shall be obtained for a dollar. For example, if the source of heat is the waste gas from an iron furnace, after you have utilized all the calories possible for heating the blast, all you can do is then so to arrange the air supply and the handling of your gases that all of the remaining heat possible is absorbed by the boiler. If you have a saw mill in which the saw dust and other waste are utilized for making steam, the furnace most uneconomical in theory may be really the best; because it may be cheaper to burn everything under the boiler than to carry it away and burn it elsewhere at an extra expense.

If, however, the one available fuel has to be purchased—and assuming that it is brought to the boiler house in the most economical manner—then we should so arrange the furnace that under all the circumstances you will evaporate the most water for a dollar.

Where a number of fuels are available (and for the purpose of this paper I am only considering the various kinds of anthracite and bituminous coal) there are several points to be considered: First, the transportation of each of the fuels to the place where it is to be used either by rail or by water; second, getting the fuel into the boiler house; third, putting the coal into the furnace; fourth, taking out the ash and the clinkers; and fifth, carrying away of the ash. It will be necessary to determine for each fuel the actual cost of these items, not in tons bought, but for each thousand heat units that are available for evaporating water and for radiation. By the analysis of the fuel you can determine the number of heat units in each kind, and from it and the analysis of the ash and stack gases approximate the amount that will be lost in the stack and in the ash pit, and thus obtain the relative value in heat units of

each ton of coal. This being done, we thus determine the exact cost at the mines of a thousand available heat units of each fuel. The transportation and hauling to the boiler house is determined by the amount of fuel purchased at the mines. The cost of shoveling into the fire depends largely upon the same facts; that is, you have to shovel more or less as the ton of coal contains more or less available heat units. But it must be remembered it is not how many heat units are in the pound of coal, but how many can be utilized. If one coal had 80 per cent. carbon, 15 per cent. ash, and 5 per cent. water, and the other had 5 per cent. ash and 15 per cent. water, the number of heat units in each would be the same, or 11,720 British thermal units per pound. But, in the first case, the number available (neglecting all losses other than that due to water) would be 10,600, and in the second, 10,488, assuming the waste products to escape at 500° F., as in one case .15 pounds of water would have to be evaporated and carried off in the stack with the same consumption of coal, while in the other it would be .05 pounds. The actual number of heat units determined by the calorimeter would be the same in both cases. When we come to taking out the ash and clinkers and hauling away the ash it would be the reverse. Water would be got rid of by evaporation—the steam going up the stack; but the ash would have to be carted away. The amount being in one case three times as much as in the other, and the amount of carbon lost in the ash would increase with the percentage of ash in the coal. (See Plate I. and Table I.)

The question of the amount of ashes to be hauled away may have an important influence upon the choice of fuel. In some cases the ashes are of use for filling up, &c.; in others, particularly in large cities, the expense of taking them away and getting rid of them may add very seriously to the cost of running the plant. In fact, I know a case of a large establishment where the cost of carting away the ashes was so serious that the owners paid a good deal more money for coal low in ash, as the gain to them was not only in the increased quantity of available combustible matter contained in the coal, but also a greater saving in the disposal of the ash.

TABLE I.

Table showing Per Cents. of the Fixed Carbon of the Fuel Lost when the Carbon in Ash Produced is from 1 to 75 Per Cent. and Ash in Fuel from 9.00 to 18.00 Per Cent.

Per Cent. of Carbon in Ash.	Per Cent. of Ash in Coal Fired.									
	9 per cent.	10 per cent.	11 per cent.	12 per cent.	13 per cent.	14 per cent.	15 per cent.	16 per cent.	17 per cent.	18 per cent.
75	31.76	35.70	39.73	43.88	48.14	52.47	56.94	61.51	66.23	71.05
70	24.70	27.75	30.89	34.11	37.43	40.80	44.27	47.83	51.51	55.26
65	19.65	22.09	24.59	27.16	29.79	32.48	35.23	37.07	41.00	43.98
60	15.87	17.84	19.86	21.93	24.07	26.23	28.47	30.76	33.11	35.52
55	12.94	14.54	16.18	17.87	19.60	21.37	23.19	24.05	26.98	28.94
50	10.59	11.90	13.24	14.63	16.04	17.49	18.98	20.50	22.08	23.68
45	8.66	9.76	10.83	11.97	13.12	14.31	15.52	16.77	18.06	19.38
40	7.05	7.92	8.82	9.74	10.69	11.66	12.64	13.66	14.72	15.79
35	5.69	6.40	7.12	7.87	8.63	9.40	10.21	11.04	11.88	12.75
30	4.53	5.10	5.66	6.27	6.87	7.43	8.12	8.78	9.45	10.14
25	3.52	3.96	4.41	4.96	5.34	5.82	6.31	6.83	7.35	7.89
20	2.64	2.97	3.30	3.65	4.02	4.36	4.74	5.13	5.52	5.92
15	1.86	2.09	2.33	2.57	2.82	3.09	3.35	3.61	3.89	4.18
10	1.17	1.32	1.47	1.62	1.77	1.93	2.10	2.27	2.45	2.62
5	.56	.63	.69	.76	.84	.91	.99	1.07	1.15	1.24
1	.10	.12	.13	.14	.16	.17	.18	.20	.22	.24

While too much stress cannot be laid upon the importance of reducing the carbon in the ash to a proper minimum, yet this must not be pushed too far, because a low percentage of ash may be obtained by firing very slowly and gently, thus reducing very greatly the efficiency of the boiler; or by allowing such excess of air to enter the furnace that the loss due to the increase of free oxygen, nitrogen, and steam in the stack may far outweigh the advantages obtained by the low percentage of ash. What is desired is the lowest percentage of carbon in the ash consistent with good, active combustion, and a reasonable excess of air in the blast. I have had a large number of specimens of ash analyzed and find that they contain between 9 and 60 per cent. of carbon, although it is not impossible to find ash with a greater or less per cent. of carbon than these. Now, the importance of this loss for different coals is not only dependent upon the percentage of carbon in the ash, but also upon the per cent. of ash in the fuel; and I give Table I., which shows, for coal containing from 9 to 18 per cent. of ash, the per cent. of the fixed carbon in the fuel lost when the carbon in the ash varies from 1 to 75 per cent. And I also give a Carbometric chart (Plate I.), which shows for each per cent. of carbon in ash for a range of 10 to 75, the per cent. of the fixed carbon utilized when the ash in the coal varies from 9 to 18 per cent. This is given so as to show at a glance how these losses vary with coals of different composition. From these two it is very evident, as might naturally be expected, that the more impure your coal is the more important it is to pay attention to the carbon in the ash. For example, if we examine the Carbometric chart we will see that if the carbon contained in the ash is 65 per cent., and the coal contains 18 per cent. of ash, we utilize 56 per cent. of the fixed carbon; while if there is but 9 per cent. of ash in the coal we utilize 80 per cent. On referring to the table, we find that under the same circumstances, when the coal contains 9 per cent. ash, 20.14 per cent. of the fixed carbon of the fuel is lost, and when it contains 18 per cent. of ash, 43.98 is lost. But when the percentage of carbon in the ash is low the difference is very much

of Air Required.

	Waste Products.	
Entering Furnace.	Lbs.	Analysis per cent.
Steam . . .	25.4820	
CO_2	293.2800	19.815
Oxygen	. . .	. . .
Nitrogen . .	755.2038	80.184

	Per cent. by wt.
. . . . .	11.50
. . . . .	2.00

Heat Given $\begin{cases} 82 \times 14650 = 1201300 \text{ B. T. U.} \\ 2 - (\frac{1}{8}^{6}) \times 62100 = 111780 \text{ B. T. U.} \end{cases}$

1313080

	T = 700° t = 60°.		T = 800° t = 60°.	
	Number of B. T. U.	Per cent. of total heat of fuel.	Number of B. T. U.	Per cent. of total heat of fuel.
By water [illegible]9	34436.394	2.622	35660.530	2.715
By CO_2 = [illegible]7	40730.726	3.101	47094.902	3.586
By nitrog[illegible]1	117835.959	8.974	136247.887	10.376
By free o[illegible]	. . . . .	. . .	. . . . .	. . .
By ash = [illegible]4	1236.158	.094	1236.158	.094
By carbon [illegible]7	29512.432	2.247	29512.432	2.247
To[illegible]8	223751 669	17.038	249751.909	19.018
Evaporati	13.4260		13.0966	
"	10.9824		10.7130	

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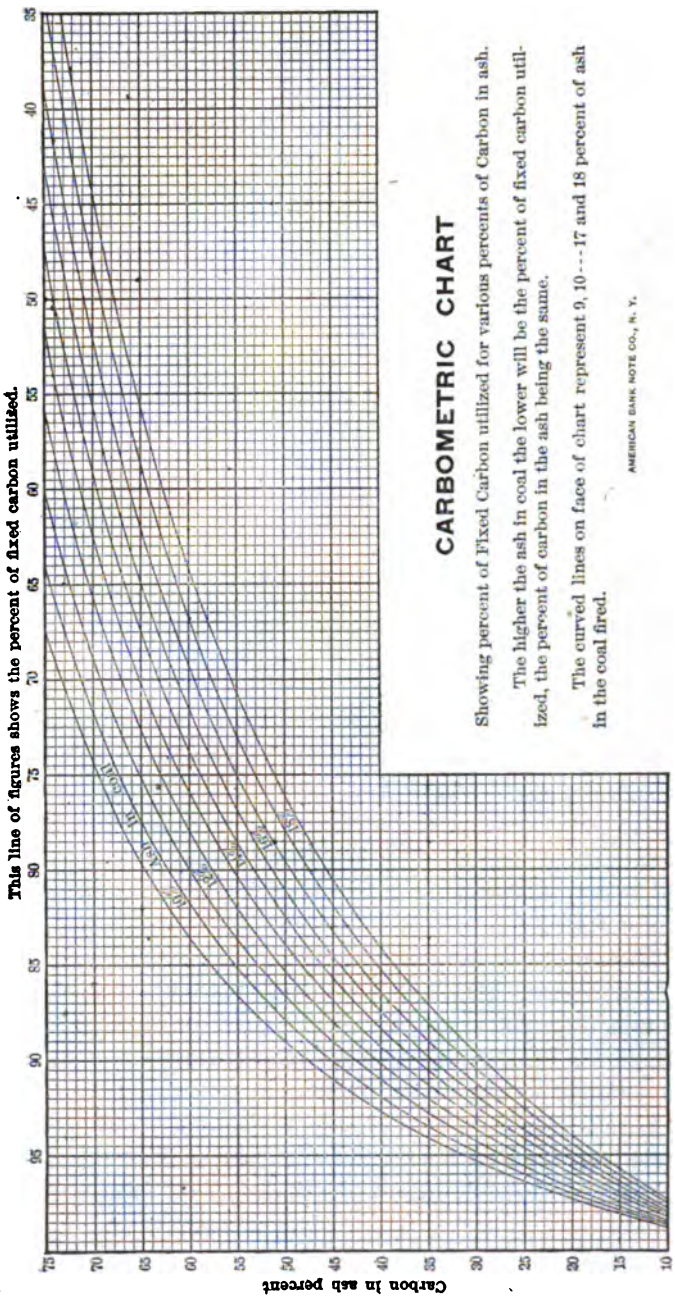
PLATE I.


This line of figures shows the percent of fixed carbon utilized.
Carbon in ash percent
CARBOMETRIC CHART
Showing percent of Fixed Carbon utilized for various percents of Carbon in ash.
The higher the ash in coal the lower will be the percent of fixed carbon utilized, the percent of carbon in the ash being the same.
The curved lines on face of chart represent 9, 10 - - - 17 and 18 percent of ash in the coal fired.
AMERICAN BANK NOTE CO., N. Y.

less. In many boiler tests sufficient attention is not paid to this subject. The experimenter simply deducts what he takes out of the ash pit from the fuel fired, calls the difference "*combustible*," and uses the figure in calculating the amount of water evaporated per pound of combustible. Now, what we want to know really is, how much water is evaporated per pound of combustible in the fuel actually put in the furnace? It is of no advantage to obtain a high evaporation with a pound of combustible by throwing away a great deal of good fuel with the ashes.

If we have purchased a given amount of coal it contains, first, carbon and hydrogen; these, by uniting with the oxygen of the air, furnish the heat; and, secondly, ash, nitrogen, oxygen, and water, all of these are useless and some worse than useless; thirdly, probably a little sulphur. This, while giving out a certain amount of heat, generates sulphurous anhydride, which has a bad effect on any iron work with which it comes in contact.

We must burn this coal with air containing oxygen, which is necessary to the combustion, and nitrogen and water, which do harm, in such a way as to obtain the greatest number of heat units in the gases passing under or through the boilers, and to evaporate with these gases the greatest amount of water at the temperature proper to furnish steam of the required pressure, and as free from moisture as possible. Of course it is not possible to do this without much loss of heat. These losses may be divided into two classes; those which are unavoidable and those which can be avoided or diminished.

The unavoidable losses are:—

First.—The heat lost by converting into steam the water contained in the coal, in the air used in burning it, and that formed by the burning of the hydrogen and heating it to the temperature at which the gases leave the stack.

Second.—The heat necessary to raise the carbonic acid gas formed by burning the carbon, the nitrogen present in the air, and the sulphurous anhydride, that may be formed by burning

the sulphur, to the stack temperature. When we have perfect combustion there will also be a certain amount of free oxygen in the stack gas, which must also be heated to the same temperature, as it is impossible not to have a certain excess of air when the combustion of the coal is complete or nearly so. There is also a certain amount of heat lost by heating the ashes which are taken from the ash pit at a temperature above that at which the coal enters the furnace, and there is a certain amount of unconsumed carbon remaining in the ash which occasions a loss; in many cases a large one. The latter can, by careful firing, be very much reduced, but can never be entirely eliminated. There is also an unavoidable loss occasioned by the radiation from the boilers and walls, which, by careful construction, and coating the plant, as far as possible, with non-conducting materials, may be reduced, but never eliminated.

The avoidable or partially avoidable losses are :—

First.—Those due to incomplete combustion, too large a proportion of the carbon may be unconsumed and pass out with the ash, a portion of the carbon instead of being burnt to carbonic acid may be converted only into carbonic oxide, and thus 69.62 per cent. of the heat units in the carbon be lost, a certain amount of hydrogen and marsh gas may be allowed to pass out of the stack, and all the heat units contained in them be lost.

Second.—Loss from excess of air. While theoretically, to burn one pound of carbon it is necessary to use only 11.50 pounds of dry air, yet in practice this is not possible, as every particle of oxygen in the air cannot be brought in intimate contact with the incandescent fuel at the proper time, so that it is necessary to use more than the theoretical quantity. But in most cases the excess is far beyond what would really be required if the firing is carefully done. This occasions great loss.

First, because all the oxygen not used and the nitrogen which accompanies it must be heated to the stack temperature,

and heat is thus lost; and secondly, because it is practically impossible to obtain air free from moisture, which must be converted into steam and heated to the stack temperature. As vapor of water carried into the fire by the air causes a loss, it is evident that the artificial introduction of moisture, either by wetting the coal or by producing the blast with steam, must necessarily increase materially the loss of heat in the stack gases.

Third.—The next avoidable cause of loss is too high a stack temperature. It is self-evident that the heating of the vast amount of stack gases, which are between ten and thirty times the weight of the coal burned, above the temperature to which they can be economically reduced, is a very serious waste, particularly if this temperature is very much in excess of what it should be.

Fourth.—Loss by removing the ashes at too high a temperature. In many cases the ashes are so hot when taken from the furnace that they have to be wetted down. Of course all this loss of heat that can be avoided, represents so many dollars thrown away.

Fifth.—Loss by radiation. It is important to have the outside surface of the plant, up to the point at which the gases cease to give up their heat, as small and as cool as possible, either by increasing the thickness of the walls, or by covering everything exposed to the air as much as conveniently can be done with non-conducting material, as the radiation increases with the area exposed, and with the difference in temperature of the surface of the walls above that of the surrounding atmosphere.

I do not refer to the coating of the steam pipes, &c., as I am not considering the use or handling of steam, but only its production.

In order to show more specifically the effect of these different losses, I shall now give some examples. Table II., hereto annexed, shows the effect of burning a hundred pounds of anthracite coal with exactly the theoretical amount of air. I assume for the purpose of illustration that the coal would contain, by analysis, what is shown in the table; and this is a fair sample of

	Waste Products.	
Enter Fur.	Lbs.	Analysis per cent.
	29.6065	.
	293.2800	9.84
	00.000	0.00
	227.6800	10.51
	509.5076	79.64

	Per cent. by wt.
11.50	85.18
2.00	14.81

Heat 1201300 B. T. U.
= 111780 B. T. U.

1313080

	T = 800° t = 60°.	
	Number of B. T. U.	Per cent. of total heat of fuel.
By wa	41432.520	3.155
By CO	47094.902	3.586
By nitr	272333.285	20.740
By CO	. . . . .	. . .
By free	36645.096	2.790
By ash	1236.158	.094
By carb	29512.432	2.247
T	428254.393	32.612

Evapor 10.835
8.863

much of the coal that is sold in the market.* Below that is given the air, divided up as needed. The amount of water contained is about that which on the average we find in the air at Drifton. I have assumed that 2 pounds of the carbon remains unconsumed and passes into the ash pit with the ashes (in which case they would contain $14\frac{81}{100}$ per cent. of carbon). This is good practice, and much below the average, although we do find less sometimes. It will be observed that this hundred pounds of coal would require 987.5 pounds of air to burn the 80 pounds of carbon and the hydrogen, it being assumed that the oxygen in the coal will take up $\frac{2}{10}$ of a pound of the hydrogen in the coal. The upper part of the second row of figures shows the portion of the fuel that passes with the air into the stack, and the lower, the ash and carbon that goes into the ash pit.

The stack gases contain all the carbon burnt in the form of carbonic acid gas, the nitrogen unchanged, and the water in the coal, the water in the air, and the water formed by the burning of the hydrogen of the coal with the oxygen of the coal and air, in the form of steam. The analysis of the stack gases would not give the steam, but the relative percentages of carbonic acid gas, nitrogen, and free oxygen, and if correct, it would give the figures in the last column.

Further down in the table is shown the heat generated in British thermal units by the 80 pounds of carbon and the 1.8 pounds of disposable hydrogen, while the total heat in the fuel is given on the right, the difference between the two being the heat units lost by the 2 pounds of carbon found in the ash; and still farther down is shown the heat lost by the water and carried out in the stack (the coal and air being assumed to be at a temperature of 60° when they enter the furnace, and the

* The analysis of the coal is taken from the results of work in our own laboratory, except the hydrogen, oxygen, and nitrogen, which are taken from the "Abstract of a Treatise by Mahler, Ingenieur Civil des Mines, for the *Societe d'Encouragement*," given in "Colliery Guardian," vol. LXIV., pages 147 and 237, according to which the volatile matter found by us would consist of 2 per cent. hydrogen, 1.60 per cent. oxygen, and 0.90 per cent. nitrogen, and the carbon which is added to the fixed carbon.

stack gases to be 400, 500, 600, 700, or 800 degrees). The first term is the heat necessary to raise the water from 60° to 212°; the second, to convert this water into steam; and the third, to raise the steam from a temperature of 212° to the stack temperature. The second line is the heat necessary to raise the carbon in the state of CO_2 from 60° to the stack temperature; the third is the same for nitrogen, and the fourth for free oxygen.

The fifth is the heat necessary to raise the ash from a temperature of 60° to 500°, which we assume to be the temperature at which it is taken from the furnace.

The sixth line shows the loss in heating the carbon to 500°, and the loss due to the carbon not being burnt. The first column gives under each stack temperature the loss in British thermal units, and the second the percentage of the total heat of fuel. The first line at the bottom shows the possible evaporation, after deducting these losses, in pounds of water from and at 212° per pound of combustible utilized, and the lower line, the possible evaporation, after this deduction, of water from and at 212° per pound of fuel. These latter are the maximum that could be obtained with no radiation, and with 14.81 per cent. of carbon in the ash.

I have not taken into consideration the radiation, which, of course, would add to the loss, but which would be impossible to determine, except by a very long and careful investigation of each apparatus. This will depend principally upon the original construction of the apparatus and upon its being preserved in good condition, and would probably be from 4 to 20 per cent. of the heat generated.

Table III. gives the same calculations under the same conditions, but assuming that double the amount of air theoretically required was used; that is, with not quite 20 pounds of air per pound of fuel. The comparison between these two tables shows how much less water per pound of fuel can be evaporated with this excess of air; and they both show how rapidly the loss increases when the temperature in the stack increases.

The results from the previous tables can be much condensed, as in Table IV., which is a shorter form of Tables II. and III.;

TABLE IV.

CONDENSED FORM OF TABLE II.

Showing Results of Combustion, &c., with the Special Object of Obtaining the Amount of Heat Lost when the Composition of Fuel, Ash, and Stack Gases, and the Temperature of the Entering Air and Escaping Gases are Known.

Entering Furnace.		Waste Products.		Losses.		
	Pounds.		Pounds.		B. T. U.	Per Ct.
Fuel: Water (w)		Stack: Steam (x)		Stack: x (1207.44 + (T—400) × 0.48)		
Fuel: Ash (p)		Stack: CO_2 (y)		Stack: y (73.78 + (T—400) × 0.217)		
Fuel: Carbon (C)		Stack: CO (s)		Stack: s (4454.986 + (T—400) × 0.2479)		
Fuel: Hydrogen (H)		Stack: Nitrogen (z)		Stack: z (82.892 + (T—400) × 0.2438)		
Fuel: Oxygen (k)		Stack: Oxygen (r)		Stack: r (73.95 + (T—400) × 0.2175)		
Fuel: Nitrogen (m)		Stack: Hydrogen (L)		Stack: L (63259.06 + (T—400) × 3.409)		
Fuel: Total		Stack: Total		Stack: Total		
Air: Oxygen (k_1)		Ash Pit: Ash, pure (p)		Ash Pit: p (107.492 + (T_1—500) × 0.2443)		
Air: Nitrogen		Ash Pit: Carbon in ash (q),		Ash Pit: q (14756.216 + (T_1 — 500) × 0.2414)		
Air: Water (w_1)						
Air: Times theoretical amount (n)		Ash Pit: Total		Ash Pit: Total		

$$\frac{\text{Heat utilized}}{\text{Total heat of fuel}} = \text{per cent. utilized.}$$

$$\frac{\text{Heat lost (except that due to radiation)}}{\text{Total heat of fuel}} = \text{per cent. lost.}$$

Total heat of fuel = $(C \times 14650) + (H - \frac{k}{8}) \times 62100)$.

by it the results of the working of any set of boilers can be shown if an analysis of the coal, an analysis of the stack gases, and an analysis of the ash, and the temperatures of the waste products have been obtained, provided the percentage of the excess of air over the theoretical quantity has been determined. How this can be done approximately from the analysis of the stack gases will be given further on.

The following is an explanation of the symbols used in Table IV.:—

By taking the weight of fuel as 100 pounds the percentages in the analysis give the weights of each component in pounds.

T is the actual stack temperature.

T_1 is the actual temperature of ashes.

p = weight of ash in fuel, or theoretical ash in ash pit, expressed in pounds.

c_2 = per cent. of carbon in ash produced, as given by analysis.

q = weight of carbon in ash produced from 100 pounds of fuel $= \frac{p \times c_2}{100 - c_2}$ or for Table II. $= \frac{11.50 \times 14.81}{100 - 14.81} = 2.$

g = weight of carbon in the fuel used, less weight of carbon in ash pit or weight of carbon burnt.

H = weight of hydrogen in fuel used.

m = weight of nitrogen in fuel used.

w = weight of water in fuel used.

e = per cent. of CO_2 by gas analysis.

f = per cent. of CO by gas analysis.

y = weight of CO_2 leaving chimney $= (\frac{e}{e+f} \times g) \times 3.666.$

s = weight of CO leaving chimney $= (\frac{f}{e+f} \times g) \times 2.333.$

H_1 = per cent. of hydrogen found by gas analysis.

L = weight of hydrogen leaving chimney $= \frac{H_1}{e} \times \frac{y}{22}$

n = number of times the theoretical air supplied, which can be obtained from Table IX., prepared for that purpose, when gas analysis is given, or by formula $n = \frac{\frac{21}{79}N}{\frac{21}{79}N - O_n}$ in which N = the per cent. of nitrogen, and O_n the per cent. of free oxygen found by gas analysis.

TABLE V.

ILLUSTRATING USE OF TABLE IV.

With Conditions as in Table II., assuming Temperature of Stack Gases to be 530° F. and Temperature of Ashes when Drawn 570° F.

	Entering Furnace.	Pounds.	Waste Products.	Pounds.	Losses.	B. T. U.	Per Ct.
Fuel	Water (w)	2.00	Steam (x)	25.482	x (1207.44 + (530—400) × 0.48)	32360.062	2.464
	Ash (p)	11.50	CO_2 (y)	293.280	y (73.78 + (530—400) × 0.217)	29911.627	2.277
	Carbon (C)	82.00	CO (s)	. . . . .	s (4454.986 + (530—400) × 0.2479)	. . . . .	. . .
	Hydrogen (H)	2.00	Nitrogen (z)	755.2038	z (82.892 + (530—400) × 0.2438)	86535.782	6.590
	Oxygen (k)	1.60	Oxygen (r)	. . . . .	r (73.95 + (530—400) × 0.2175)	. . . . .	. . .
	Nitrogen (m)	.90	Hydrogen (H)	. . . . .	L (63259.06 + (530—400) × 3.409)	. . . . .	. . .
	Total	100.00	Total	1073.9658	Total loss in stack	148807.471	11.331
Air	Oxygen (k_1)	227.68	Ash, pure (p)	11.50	p (107.492 + (570—500) × 0.2443)	1432.819	.109
	Nitrogen	754.3038	Carbon in ash (q)	2.00	q (14756.216 + (570—500) × 0.2414)	29550.228	2.250
	Water (w_1)	5.482					
	Times theoretical amount (n)	1.000					
			Total	13.50	Total loss in stack and ash pit	179790.518	13.690

Total heat of fuel = (C × 14650) + (H—$\frac{k}{8}$) × 62100 = 1313080 B. T. U. . . . . .

$\frac{\text{Heat utilized}}{\text{Total heat of fuel}}$ = 86.310 per cent. utilized.

$\frac{\text{Heat lost (excepting that due to radiation)}}{\text{Total heat of fuel}}$ = 13.690 per cent. lost.

k = weight of oxygen in fuel used (from ultimate analysis).

k_2 = weight of theoretical oxygen required = $(.7273 \times y) + (.5715 \times s) + (8\ \mathrm{H}-k)$.

k_1 = weight of oxygen brought in by the air = $k_2 \times n$.

l = weight of dry air supplied = $k_1 \times 4.313$.

w_1 = weight of water in air supplied, which can readily be obtained from tables if the temperature of the air, its relative humidity, and the height of barometer is known.

r = weight of free oxygen leaving chimney = $k_1 - k_2$ or $k_2 \times n - k_2 = k_2 (n-1)$.

z = weight of nitrogen leaving chimney = $(k_1 \times 3.313) + m$.

x = weight of total water or steam leaving chimney = $w + w_1 + 9\ \mathrm{H}$.

Table V. is an illustration of the use of Table IV. I have assumed the composition of coal, air, ash, and stack gases to be as in Table II., and that the temperature of the stack gases is 530° and temperature of ashes 570°.

In Table IV. I have provided also for the introduction in the analysis of the stack gases of carbonic oxide and hydrogen, which sometimes are found, but which are always evidences of bad firing.

In order to convert Tables II. and III. into dollars and cents, which may possibly be of a greater interest, I assume that the coal used is in one case anthracite buckwheat, costing at the mines 50 cents, and that the cost of transportation from mines to the point where it is used, including expenses of hauling to the boiler house, is $2; and in the other case, pea coal, costing at the mines $1.50, and that the cost of transportation was the same as for buckwheat.

Column A, Table VI., represents results with coal costing 50 cents, burned at mines with theoretical quantity of air.

Column B represents results with coal costing $2.50 at mill or furnace, burned with theoretical quantity of air.

Column C represents results with coal as in column A, but burned with twice the theoretical quantity of air.

Column D represents results with coal as in B, but burned with twice the theoretical quantity of air.

ço at Mill or Furnace.

		T = 800° t = 60°.			
	).	A.	B.	C.	D.
Loss in stack	By .0761	$0.0135	$0.0678	$0.0157	$0.0788
	.0775	.0179	.0896	.0179	.0896
	. . .	. . . .	. . . .	. . . .	. . . .
	.4484	.0518	.2594	.1037	.5185
	.0603	. . . .	. . . .	.0139	.0697
Loss in ash pit	.0023	.0004	.0023	.0004	.0023
	.0561	.0112	.0561	.0112	.0561
	T .7207	$0.0948	$0.4752	$0.1628	$0.8150
Actua	.7793	$0.4052	$2.0248	$0.3372	$1.6850
Fuel ing. wat 212	.0119	.0020	.0104	.0025	.0125
Fuel pow	.0041	.0007	.0035	.0008	.0043

Mill or Furnace.

		T = 800° t = 60°.			
	).	A.	B.	C.	D.
Loss in stack	.1065	$0.0405	$0.0949	$0.0471	$0.1103
	.1085	.0537	.1254	.0537	.1254
	. . .	. . . .	. . . .	. . . .	. . . .
	.6277	.1554	.3631	.3111	.7259
	.0844	. . . .	. . . .	.0417	.0975
Loss in ash	.0032	.0012	.0032	.0012	.0032
	.0785	.0336	.0785	.0336	.0785
	.0088	$0.2844	$0.6651	$0.4484	$1.1408
Act	.4912	$1.2156	$2.8349	$1.0516	$2.3592
Fuel in wa 21	.0166	.0062	.0145	.0075	.0176
Fuel po	.0057	.0021	.0050	.0026	.0060

Table VII. shows similar results, but with fuel costing $1.50 at mines and $3.50 at mill or furnace.

From these tables it can be seen, first, how the economy in using cheap fuel decreases as the distance from the mine increases; in other words, how important a factor the cost of transportation is in the choosing of a fuel. Second, how much more important it is, the more valuable fuel you use, and the further you are from its point of production, that you pay attention to avoidable causes of loss. Thus, when using buckwheat coal at the mill or furnace with double the quantity of air, and at a stack temperature of 800° instead of the theoretical quantity of air and a stack temperature of 400°, the loss is $0.5379 per ton, while with pea coal the loss is $0.7530. So that if you were burning 10,000 tons of pea coal a year, you could afford to spend, to bring about the better result, a sum of money on which $7530 would give a fair interest and profit, while if you were burning buckwheat coal you could only afford to spend an amount on which $5379 would do so. At the mines, buckwheat coal with double the quantity of air and at a stack temperature of 800°, instead of the theoretical quantity of air with stack at 400°, the loss per ton would be $0.1075, while with pea coal the loss would be $0.2825, so that at the mines you could only afford to spend in improving your plant a sum on which $1075 and $2825, respectively, would give a fair interest and profit.

The same remarks will apply to carbon in the ash, &c.

Thus far we have assumed that the combustion in the furnace was complete; that is to say, that all the hydrogen was burnt to water and that all the carbon was burnt to carbonic acid gas. This, however, is generally not the case with the more modern methods of burning coal by forced draft, particularly when a steam jet is used. In the latter case it is not uncommon to find 6 to 10 per cent. of carbonic oxide and from 2 to 6 per cent. of hydrogen in the stack gases. Of course, all the heat units of the hydrogen that goes up the stack is lost, and 69.62 per cent. of all the heat units of the carbon which is burnt to carbonic oxide is lost. Carbonic oxide is almost always formed

unless the bed of coal in the furnace is thin; when the bed is thick the air on reaching the lower part of the bed of incandescent fuel converts the carbon into carbonic acid, part of which in passing through the incandescent carbon is converted into carbonic oxide, the latter, to a greater or less extent, burns in the furnace uniting with the free oxygen in the gases that have traversed the bed of fuel. Carbonic oxide will not unite with the oxygen unless the temperature is pretty high—variously estimated from 1150° to 1500° F., so that if the gases are carried through the furnace too rapidly, and reach the cooler parts of the boiler before all the carbonic oxide has been burnt, it will pass out of the stack unconsumed.

Hydrogen is not often found in any great quantity in the stack gases, unless the blast is produced by a steam jet, in which case, as the steam passes through the incandescent carbon, dissociation takes place and a large quantity of hydrogen and carbonic oxide forms, which does not burn except when there is a very large excess of air and the other conditions are favorable, otherwise much of the carbonic oxide and hydrogen pass out of the stack, causing very great loss of otherwise available heat. For this reason the analysis of the stack gases, while always important, is especially so when the steam jet blast is used, as I have found to my chagrin in studying its use at our works. I would here call special attention to the importance of not allowing the products of combustion to pass too rapidly through or under the boiler. There is a velocity below which there is loss in the efficiency of the boiler, that is to say, in the amount of water evaporated per square foot of heating surface, and there is a velocity above which the percentage of unconsumed carbonic oxide, and possibly hydrogen (due to the fact that they are carried to the cooler part of the boiler too soon), becomes so great as to diminish very much the amount of water evaporated per pound of fuel. We have found that in some cases where the passage of the gas through the boiler was very much obstructed and interfered with, it was necessary, to get the best results, to produce a suction in the stack; while in other cases, an instance

of which was the Stirling boiler plant, with the stoker, referred to in the last part of this paper, we found that by closing the damper we could burn less coal, reduce our blast, and evaporate more water per pound of coal and per hour. The reason was, first, that a part of the carbonic oxide, which would otherwise have been burnt, passed up the stack unconsumed; because it was carried so rapidly to the cooler part of the boiler that it could not unite with the free oxygen in the gases and burn. Second, that owing to the strong stack draft a much larger excess of air passed through and over the grate, cooling off the furnace and increasing the quantity of heat carried up the stack.

In order to discuss the subject of the effect of free oxygen, carbonic oxide, and hydrogen in the stack, I give two tables.

TABLE VIII.

Giving Number of Times the Theoretical Air Supplied and Per cent. of Heat Lost by Escaping Gases when Carbon is Burned to Carbonic Anhydride (CO_2).

1	2	3	1	2	3
Gas Analysis. Combustible in Fuel Burned = 100 % Carbon.	Number of Times the Theoretical Air Supplied.	Per Cent. of Heat Lost When (T-t) = 500° F.	Gas Analysis. Combustible in Fuel Burned = 100 % Carbon.	Number of Times the Theoretical Air Supplied.	Per Cent. of Heat Lost When (T-t) = 500° F.
$CO_2 = 21$, $N = 79$	1.00	10.1535	$CO_2 = 10$, $O = 11$, $N = 79$	2.10	20.4288
$CO_2 = 20$, $O = 1$, $N = 79$	1.05	10.6205	$CO_2 = 9$, $O = 12$, $N = 79$	2.33	22.5773
$CO_2 = 19$, $O = 2$, $N = 79$	1.10	11.0876	$CO_2 = 8$, $O = 13$, $N = 79$	2.62	25.2862
$CO_2 = 18$, $O = 3$, $N = 79$	1.17	11.7415	$CO_2 = 7$, $O = 14$, $N = 79$	3.00	28.8359
$CO_2 = 17$, $O = 4$, $N = 79$	1.23	12.3019	$CO_2 = 6$, $O = 15$, $N = 79$	3.50	33.5065
$CO_2 = 16$, $O = 5$, $N = 79$	1.31	13.0492	$CO_2 = 5$, $O = 16$, $N = 79$	4.20	40.0454
$CO_2 = 15$, $O = 6$, $N = 79$	1.40	13.8899	$CO_2 = 4$, $O = 17$, $N = 79$	5.25	49.8536
$CO_2 = 14$, $O = 7$, $N = 79$	1.50	14.8241	$CO_2 = 3$, $O = 18$, $N = 79$	7.00	66.2008
$CO_2 = 13$, $O = 8$, $N = 79$	1.61	15.8516	$CO_2 = 2$, $O = 19$, $N = 79$	10.50	98.8950
$CO_2 = 12$, $O = 9$, $N = 79$	1.75	17.1594	$CO_2 = 1$, $O = 20$, $N = 79$	21.00	196.9779
$CO_2 = 11$, $O = 10$, $N = 79$	1.91	18.6540			

In this table it is assumed that there is no carbonic oxide present in the stack gases and no hydrogen either in the fuel or stack gases, in which case the $CO_2 + O$ will always be 21 per cent. and the nitrogen 79 per cent. The second column shows the number of times the theoretical air supplied to the fuel in each case for the gas analysis given in column 1, calculated by the formula $n = \frac{\frac{21}{79}N}{\frac{21}{79}N - O_n}$ or $= \frac{CO_2 + O_n}{CO_2}$ and in which "n" is the number of times the theoretical air, O_n the free oxygen, and N the nitrogen in the gas analysis.

Column 3 gives the per cent. of heat carried out by the escaping gases when the stack temperature is 500° F. above that of the atmosphere. The formulæ for calculating this is: Heat lost $= \frac{[(11.5 \times n) + 1] \times .238 \times (T\text{-}t)}{14650}$, which equals $[(11.5 \times n) + 1] \times .0081228$, when $(T-t) = 500°$.

It will be observed that the per cent. of heat lost when the carbonic acid is only 1 per cent. is 196.9. This might occur when the fire was being cleaned, and practically no combustion was taking place, but the air passing through the boiler was robbing the brickwork and boiler of its heat, although it is probable at such a time a temperature of 500° in the stack would not be reached.

TABLE IX.

Giving Number of Times the Theoretical Quantity of Air Supplied, with Various Gas Analyses.

1	2	3	4	5
$CO_2 + CO$.	$N = 79$ $CO_2 + CO + O = 21$.	$N = 80$ $CO_2 + CO + O = 20$.	$N = 81$ $CO_2 + CO + O = 19$.	$N = 82$ $CO_2 + CO + O = 18$.
21	1.00	. . . . .	. . . . .	. . . . .
20	1.05	1.00	. . . . .	. . . . .
19	1.10	1.05	1.00	. . . . .
18	1.17	1.10	1.05	1.00
17	1.23	1.16	1.10	1.05
16	1.31	1.23	1.16	1.10
15	1.40	1.31	1.23	1.16
14	1.50	1.39	1.30	1.22
13	1.61	1.49	1.39	1.30
12	1.75	1.60	1.48	1.38
11	1.91	1.73	1.59	1.47
10	2.10	1.89	1.72	1.58
9	2.33	2.07	1.87	1.70
8	2.62	2.29	2.04	1.85
7	3.00	2.57	2.26	2.02
6	3.50	2.92	2.52	2.23
5	4.20	3.39	2.86	2.48
4	5.25	4.05	3.30	2.79
3	7.00	5.00	3.89	3.20
2	10.50	6.53	4.76	3.76
1	21.00	9.43	6.10	4.54

This table shows the number of times the theoretical quantity of air supplied to a furnace, calculated from gas analysis for various per cents of CO_2 and CO, when the gas analysis approaches either of the four conditions noted at the head of columns 2, 3, 4, and 5.

These conditions can only exist when hydrogen is present in the fuel burnt, and has been converted into water. This hydrogen in each case taking up the oxygen* which cannot be accounted for in the gas analysis.

The table is calculated according to the formula $n = \frac{\frac{21}{79}N}{\frac{21}{79}N - O_n}$ $= \frac{1}{1 - \frac{79}{21}\frac{O_n}{N}}$ in which "n" is the number of times the theoretical air, "N" the total nitrogen, and "O_n" the free oxygen found in the gases. This formula is only true when the conditions are as given above, *i. e.*, when the hydrogen has taken up the oxygen not accounted for in the gas analysis. This is the cause of the apparent small excess of air in the last three columns, more oxygen has combined with hydrogen, thus increasing the amount of oxygen used and lowering the free oxygen, and thereby the number of times the theoretical air used.

I now give in Table X. a number of analyses of stack gases from boiler furnaces made by Mr. Alexander H. Sherrerd, of Scranton, Pa. In this case all the fires had forced draft produced by steam jet under the grate. The hydrogen and marsh gas is only determined in some cases, but it will be observed that a quite appreciable percentage of hydrogen and carbonic oxide is often found.

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* As the oxygen brought in by the air is always $\frac{21}{79}$ of the total nitrogen, if the sum of the oxygen present by volume, *i. e.*, $CO_2 + \frac{1}{2}CO + O_n$, does not amount to this figure, it means that the rest has been used to combine with hydrogen. For example: In column 3 where N equals 80, the oxygen brought in equals $\frac{21}{79}$ of 80 or 21.26, and if $CO_2 + CO$ in column 1 equal 15, then as in column 3, $CO_2 + CO + O$ is equal to 20, we have a free oxygen of 5.00. This makes the oxygen accounted for when the CO is 1.00 per cent. equal to 14.00 + .50 + 5.00 or 19.50, by volume, the difference of 1.76 of oxygen having combined with hydrogen.

TABLE X.

Analysis of Boiler Furnace Gases at Works of Lackawanna Iron and Steel Company, by Alex. H. Sherrerd, Scranton, Pa.

No.	Date.	Boilers, Stacks, Condition of Fire.	CO_2.	O.	CO.	N.	CH_4.	H.
1	Sept. 6, 1887	Small boiler, deep, bright, hot fire, plenty gas, had not been shaken for three hours; blast strong	14.2	4.2	3.0	78.6	. . .	. . .
2	" "	Small boiler, little later	11.0	3.4	7.6	78.0	. . .	. . .
3	" "	Small boiler, after another fire	8.6	5.0	9.6	76.8	. . .	. . .
4	Sept. 7, 1887	Another boiler, deep, bright fire	16.5	4.8	. . .	78.7	. . .	. . .
5	Sept. 8, 1887	Same, deep, bright fire	16.0	1.4	4.0	78.6	. . .	. . .
6	" "	Same, deep, bright fire	13.1	0.6	10.9	75.4	. . .	. . .
7	" "	Same, deep, bright fire	17.4	0.4	3.4	78.8	. . .	. . .
8	Sept. 9, 1887	Large boiler, deep, bright fire	15.8	3.8	2.3	76.5	1.6	. . .
9	Sept. 10, 1887	Ordinary size boiler at steel works, deep, bright fire	10.0	1.4	14.2	68.8	1.5	3.1
10	Sept. 12, 1887	Large boiler	15.6	3.0	. . .	80.1	1.5	0.0
11	Oct. 25, 1887	Boiler No. 2, old fire	16.8	1.8	1.21	80.2	. . .	. . .
12	" "	Same boiler, later	12.8	6.9	1.3	79.0	. . .	. . .
13	Oct. 26, 1887	Boiler No. 3, thin fire, just put on small amount of culm,	13.1	5.0	0.7	81.2	. . .	. . .
14	" "	Same boiler, good fire	16.5	3.3	0.9	71.3	. . .	. . .
15	" "	Boiler No. 5, short stack, average fire	13.7	2.4	4.9	79.0	. . .	. . .
16	" "	Same after coaling	11.5	2.7	7.2	78.6	. . .	. . .
17	Oct. 27, 1887	Boiler No. 8, middle size, average good fire	13.3	5.5	0.9	80.3	. . .	. . .
18	" "	Same, after coaling	10.8	2.0	9.5	77.7	. . .	. . .
19	" "	Boiler No. 5, good, bright fire	14.5	0.9	6.2	78.4	. . .	. . .
20	" "	Boiler No. 2, just after firing	11.9	1.9	5.6	80.6	. . .	. . .
21	Oct. 31, 1887	Boiler No. 2, after coal (3 minutes)	12.5	0.9	10.0	74.0	1 9	0.7
22	" "	Boiler No. 2, after coal (9 minutes)	15.5	3.5	0.3	79.5	1.2	0.0
23	Nov. 1, 1887	Boiler No. 3, new fire, not much body, 5 minutes after coal, many blow holes	12.5	5.1	. . .	80.5	1.9	0.0
24	" "	Same, after another layer of coal burned up bright, chamber half full of gas	10.3	6.2	. . .	80.1	3.4	0.0
25	Nov. 2, 1887	Boiler No. 5, short stack, ¼-hour after cleaning, 5 minutes after coaling, fire not deep or bright	12.6	0.4	8.8	76.1	1.4	0.7
26	" "	Same 9 minutes after, bright	15.9	1.6	1.0	80.7	0.8	0.0
27	" "	Same ¼-hour before cleaning, deep fire, chamber full of gas	13.6	0.7	7.3	75.9	2.5	0.0
28	Nov. 3, 1887	Boiler No. 3, middle size, ¼-hour before cleaning, 9 minutes after coaling, bright, A. M.	13.0	0.7	7.5	77.6	1.2	0.0
29	" "	Same condition, P. M.	14.3	0.8	5.0	78.4	1.3	0.0

The following table, compiled from a very valuable work,* gives the analyses of the stack gases of a large number of boiler tests made at the Industrial Exhibition at Düsseldorf in 1880, and shows how much they vary. Bituminous coal was used in all cases except one (semi-bituminous).

TABLE XI.

Analyses of Stack Gases as Made at the Engine and Boiler Trials at the Gewerbe-Ausstellung in Düsseldorf, 1880.*

CO_2	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.
4.8	14.2	.2	80.80	5.60	13.90	.40	80.10	12.30	6.40	.90	80.40
6.5	13.3	.1	80.10	5.30	13.60	1.00	80.10	11.90	6.60	.40	81.10
6.9	12.0	.2	80.90	5.30	13.70	1.20	79.80	12.40	6.00	.40	81.20
5.4	13.1	.3	81.20	4.75	14.65	.60	80.00	12.10	4.30	2.80	80.80
7.85	10.75	2.10	79.30	4.30	15.20	.40	80.10	12.30	6.00	1.20	80.50
9.06	8.60	1.95	80.45	3.50	16.10	.40	80.00	12.40	6.00	.20	81.40
7.50	11.30	.95	80.25	3.30	16.20	.50	80.00	12.60	5.90	.20	81.30
6.70	12.40	.70	80.10	7.70	11.20	.40	80.70	12.20	4.30	2.70	80.80
7.20	11.75	.15	80.90	13.40	4.10	1.20	81.30	11.00	7.60	.60	80.80
10.95	7.40	.85	80.80	12.30	5.78	1.02	80.90	9.00	11.40	. .	79.60
10.20	8.40	.40	81.00	12.90	5.40	1.50	80.20	10.20	9.20	. .	80.60
9.80	8.90	.20	81.10	13.10	3.30	3.00	80.60	11.80	6.80	. .	81.40
6.80	12.00	.85	80.35	13.30	4.00	1.60	80.10	12.60	5.60	.20	81.60
9.75	9.45	. .	80.80	12.00	5.70	.60	80.70	11.10	7.80	. .	81.10
9.50	9.60	.10	80.80	10.60	7.40	.20	81.80	11.60	7.00	.30	81.10
11.10	7.55	.20	81.15	11.20	7.90	.90	80.00	13.60	4.40	.20	81.80
9.90	8.50	.15	81.45	10.50	8.50	.40	80.60	11.80	5.10	1.70	81.40
8.15	10.75	.20	80.95	9.20	9.00	2.00	79.30	11.70	5.80	1.30	81.20
8.40	10.60	.60	80.40	10.30	8.30	. .	81.40	11.70	7.40	.60	81.30
8.00	11.05	.65	80.30	13.30	4.30	1.00	81.40	13.10	4.90	.20	81.80
8.05	10.00	.60	81.35	13.00	4.50	1.00	81.50	12.00	4.90	1.50	81.60
8.60	8.25	2.25	80.90	12.60	5.60	.50	81.30	11.30	5.50	2.10	81.10
9.55	8.20	1.75	80.50	13.30	2.80	.69	83.30	10.70	5.90	2.80	80.60
8.70	10.20	.50	80.60	11.82	2.98	1.20	84.00	13.00	5.20	. .	81.80
5.50	13.60	.25	80.60	12.14	3.44	.34	84.08	13.10	5.10	. .	81.80
7.80	11.00	.95	80.25	14.04	3.14	1.62	81.20	10.50	8.80	. .	80.70
5.45	14.05	.45	80.05	13.84	3.42	.54	82.18	10.80	8.80	. .	80.40
6.00	13.20	.30	80.50	12.43	2.59	5.30	79.68	11.72	6.08	. .	82.20
5.20	14.25	.25	80.30	11.92	3.24	3.88	80.26	13.30	5.40	. .	81.30
6.95	11.75	.10	81.20	12.30	5.55	.65	81.50	12.20	6.80	. .	81.00
10.20	8.60	. .	81.10	13.08	5.02	.50	81.40	13.10	5.00	.40	81.50
10.20	8.50	.10	81.20	13.90	4.50	.75	80.85	13.20	5.00	. .	81.80
9.00	10.05	.10	80.85	12.70	3.60	4.00	79.70	13.20	5.30	. .	81.50
8.10	10.70	. .	81.20	13.20	5.10	.70	81.00	12.80	5.70	. .	81.50
14.60	4.30	. .	81.10	12.60	5.80	1.60	80.00	13.60	5.20	.10	81.10
10.15	8.65	.35	80.85	12.50	6.50	1.30	79.70	13.00	4.80	.50	81.70
11.40	7.55	. .	81.05	11.30	7.50	.10	81.10	12.50	5.70	.30	81.50
11.70	6.40	.40	81.50	10.60	8.90	. .	80.50	13.20	4.90	.40	81.90
12.25	5.70	1.25	80.80	10.20	9.30	.10	80.40	12.00	6.50	. .	81.50
10.00	9.10	.80	80.10	10.10	7.10	.40	80.40	12.30	4.10	2.60	81.00
9.95	8.95	.60	80.50	12.90	5.10	1.30	80.70				
6.50	12.60	.70	80.20	13.00	5.90	.60	80.50				

* "Die Untersuchungen an Dampfmaschinen und Dampfkesseln, und an einigen Rheinischen und Westfälischen Kohlensorten auf der Gewerbe-Ausstellung in Düsseldorf in 1880," herausgegeben von H. v. Reiche und F. Böcking, Aachen, 1881. Verlag von J. A. Mayer.

Further examples may be found in the following very valuable paper:—

Report of a Series of Trials of a Warm-Blast Apparatus for Transferring part of the Heat of Escaping Flue Gases to the Furnace.

Paper CLXXXIII. read before the American Society of Mechanical Engineers, by J. C. Hoadley, vol. VI., page 676 (1885), also published by John Wiley & Sons, New York, under the title "Warm-Blast Steam Boiler Furnace."

In order to show the effect of the carbonic oxide, marsh gas, and hydrogen I have taken two examples of the gas analyses by Mr. Sherrerd and one hypothetical case, which agrees with what we found in practice, assuming that the composition of coal and the composition of ash is the same as given in Table II., although I am convinced that the amount of carbon in the ash was much greater in every case. These have been worked out in the abbreviated form suggested in Table IV., and the results are given in Tables XII. and XIII., which show how great is the loss or waste due to carbonic oxide and hydrogen in the stack gases. In the tables given by H. v. Reiche, all of which refer to bituminous coal, we find the carbonic acid running from 3.30 to 14.60 (see Table XI.), the carbonic oxide from 0 to 5.30, the free oxygen from 2.80 to 16.40, and the nitrogen from 79.30 to 84.8. These experiments were made very carefully, with natural draught, under the direction of men who thoroughly understood the problem, practically and scientifically, and are quoted to show what great variety there may be in the composition of the furnace gases, a fact to which I cannot too often call attention.

TABLE XII.

Giving Losses of Heat with Stack Gases as given in Gas Analysis No. 9 of Table X.

Entering Furnace.		Waste Products.		Losses.		
	Pounds.		Pounds.		B. T. U.	Per Ct.
Fuel — Water (w)	2.000	Stack — Steam (x)	5.7108	x (1207.44+(400 −400) ×0.48)	6895.448	.527
Ash (p)	11.500	CO_2 (y)	115.3192	y (73.78 + (400—400) × 0.217)	8508.250	.651
Carbon (C)	82.844	CO (s)	104.2300	s(4454.986+(400—400)×0.2479)	448305.191	34.307
Hydrogen (H)	1.638	Nitrogen (z)	511.5015	z (82.892+(400—400) × 0.2438)	42399.382	3.244
Oxygen (k)	1.117	Oxygen (r)	11.7985	r (73.95 + (400—400) × 0.2175)	872.499	.066
Nitrogen (m)	.900	Hydrogen (L)	1.6294	L(63259.06+(400—400)×3.409)	103074.312	7.888
		Marsh gas (M)	6.2891	M(26714.12+(400—400)×0.593)	168007.772	12.857
Total	100.000	Total	756.4785	Total loss in stack	778062.854	59.540
Air — Oxygen (k_1)	154.1205	Ash Pit — Ash, pure (p)	11.50	p (107.492+(500—500)×0.2443)	1236.158	.094
Nitrogen	510.6015	Carbon in ash (q)	2.00	q (14756.216 + (500—500) × 0.2414)	29512.432	2 258
Water (w_1)	3.7108					
Times theoretical amount (n)	1.0829	Total	13.50	Total loss in stack and ash pit	808811.444	61.892

Total heat of fuel = C × 14650 + $(H-\frac{k}{8}) \times 62100$ = 1306715.24 B. T. U. . . . . .

$\frac{\text{Heat utilized}}{\text{Total heat of fuel}}$ = 38.108 per cent. utilized.

$\frac{\text{Heat lost (excepting that due to radiation)}}{\text{Total heat of fuel}}$ = 61.892 per cent. lost.

TABLE XIII.

Giving Losses of Heat with Stack Gases as given in Gas Analysis No. 21 of Table X.

Entering Furnace.		Waste Products.		Losses.		
	Pounds.		Pounds.		B. T. U.	Per Ct.
Fuel — Water (w)	2.000	Stack — Steam (x)	19.9136	Stack — x (1207.44+(400°—400°)×0.48)	24044.477	1.817
Fuel — Ash (p)	11.500	Stack — CO_2 (y)	150.3119	Stack — y (73.78 + (400—400) × 0.217)	11090.119	.838
Fuel — Carbon (C)	82.050	Stack — CO (s)	76.5328	Stack — s(4454.986+(400—400)×0.2479)	340952.552	25.768
Fuel — Hydrogen (H)	1.950	Stack — Nitrogen (z)	569.3263	Stack — z(82.892 + (400—400) × 0.2438)	47192.595	3.566
Fuel — Oxygen (k)	1.600	Stack — Oxygen (r)	7.8427	Stack — r (73.95 + (400—400) × 0.2175)	579.967	.043
Fuel — Nitrogen (n)	.900	Stack — Hydrogen (L)	.3826	Stack — L (63259.06+(400—400)×3.409)	24202.916	1.829
		Stack — Marsh Gas (M)	8.3081	Stack — M(26714.12+(400—400)×0.593)	221943.580	16.774
Fuel — Total	100.00	Stack — Total	832.6180	Stack — Total loss in stack	670006.206	50.635
Air — Oxygen (k_1)	171.5744	Ash Pit — Ash, pure (p)	11.50	Ash Pit — p (107.492+(500—500)×0.2443)	1236.158	.093
Air — Nitrogen	568.4263	Ash Pit — Carbon in ash (q)	2.00	Ash Pit — q (14756.216 + (500—500) × 0.2414)	29512.432	2.230
Air — Water (w_1)	4.1082					
Air — Times theoretical amount (n)	1.0479					
		Ash Pit — Total	13.50	Ash Pit — Total loss in stack and ash pit	700754.796	52.958

Total heat of fuel = $C \times 14650 + (H - \frac{k}{8}) \times$ 62100 = 1323127.5 B. T. U.

$\frac{\text{Heat utilized}}{\text{Total heat of fuel}}$ = 47.042 per cent. utilized.

$\frac{\text{Heat lost (excepting that due to radiation)}}{\text{Total heat of fuel}}$ = 52.958 per cent. lost.

TABLE XIV.

Giving Losses of Heat when Composition of Fuel and Air is as per Column 1 and Stack Gases as follows: CO_2, 11.85, CO, 12.83, O, none, and N, 75.31 per cent.

Entering Furnace.		Waste Products.		Losses.		
	Pounds.		Pounds.		B. T. U.	Per Ct.
Fuel — Water (w)	2.00	Stack — Steam (x)	24.1082	x (1207.44 + (400—400) × 0.48)	29109.205	2.216
Fuel — Ash (p)	11.50	Stack — CO_2 (y)	141.5639	y (73.78 + (400—400) × 0.217)	10442.592	.795
Fuel — Carbon (C)	82.00	Stack — CO (s)	96.5488	s (4454.986 + (400—400) × 0.2479)	430123.552	32.756
Fuel — Hydrogen (H)	2.00	Stack — Nitrogen (z)	572.4498	z (82.892 + (400—400) × 0.2438)	47451.508	3.613
Fuel — Nitrogen (m)	.90	Stack — Oxygen (r)	. . . . .	r (73.95 + (400—400) × 0.2175)	. . . . .	. . .
Fuel — Oxygen (r)	1.60	Stack — Hydrogen (L)	. . . . .	L (63259.06 + (400—400) × 3.409)	. . . . .	. . .
Total	100.00	Total	834.6437	Total loss in stack	517126.857	39.380
Air — Oxygen (k_1)	172.5173	Ash Pit — Ash, pure (p)	11.50	p (107.492 + (500—500) × 0.2443)	1236.158	.094
Air — Nitrogen	571.5498	Ash Pit — Carbon in ash (q)	2.00	q (14756.216 + (500—500) × 0.2414)	29512.432	2.247
Air — Water (w_1)	4.1082					
Air — Times theoretical amount (n)	1.0000					
		Total	13.50	Total loss in stack and ash pit,	547875.447	41.721

Total heat of fuel = C × 14650 + $(H-\frac{k}{8}) \times$ 62100 = 1313080 B. T. U.

$\frac{\text{Heat utilized}}{\text{Total heat of fuel}}$ = 58.279 per cent. utilized.

$\frac{\text{Heat lost (excepting that due to radiation)}}{\text{Total heat of fuel.}}$ = 41.721 per cent lost.

I now give the results of a test made at Drifton on one of our stoker plants, which consisted of three plain cylinder boilers, 36 feet long, 34 inches in diameter, with two mud drums 22 feet long and 34 inches in diameter under them and erected in the old-fashioned way, at the back end of which was placed a tubular boiler 60 inches in diameter and 12 feet long, with 299—2-inch tubes, through which the products of combustion passed after leaving the cylinder boilers, the tubes of this boiler forming a continuation of the flue and leading directly to the stack, which was of sheet iron. As the top of the shell was below the water line in the cylinder boilers the water in the tubular boiler filled it completely, the cooler water passing into the bottom of the tubular boiler and the hot water and steam passing out of the top into the cylinder boilers, in which was the steam space. This test was made some time ago—the gas, ash, and the coal being analyzed. From this data we have worked out on the form

TABLE XV.

THE COXE IRON MANUFACTURING COMPANY,
TESTING DEPARTMENT,

DRIFTON, PA., August 9th, 1894.

Report of Test of Cylinder Boilers Equipped with a 4-foot Coxe Mechanical Stoker and Burning Anthracite Buckwheat Coal.

1	Duration of test	11 hours
2	Pounds of water evaporated per pound of dry coal—actual conditions	8.30
3	Pounds of water evaporated per pound of dry coal, from and at 212° F.	9.68
4	Pounds of water evaporated per pound of combustible, from and at 212° F.	11.00
5	Pounds of water evaporated from and at 212° F. per hour	8059.8
6	" coal per square foot of grate per hour	20.81
7	" " hour	832.36
8	Average temperature of escaping gases	540°
9	Horse power actually developed	257
10	Square feet of heating surface per horse power	8.23
11	Percentage under or overrated capacity (rating indefinite)	....
12	Moisture in steam, not determined	....
13	" coal as fired	2.49
14	Per cent. of ash in ash pit	12.05
15	Carbon in ash	18.68
16	Pressure, average, of steam	101
17	" " blast in inches of water in entrance chamber	1⅜
18	Temperature of feed water, average	90°
19	" outside air, average	73°
20	Percentage of steam used to run plant (a 4-foot stoker and No. 7 Sturtevant fan, the latter set up to run an additional 6-foot stoker)	3.91

Analysis of coal:	Moisture	1.55%
	Volatile combustible matter	3.91%
	Ash	10.35%
	Carbon (fixed)	84.29%
Slate test:	Pure coal, specific gravity below 1.72	94.79%
	Slate and bone, specific gravity above 1.72	5.20%
Sizing test:	Pea, through ⅞-inch and over $\frac{9}{16}$-inch mesh	12.43%
	Buckwheat " $\frac{9}{16}$ " $\frac{3}{8}$ "	59.85%
	Rice, " ⅜ " $\frac{3}{16}$ "	23.44%
	Barley, " $\frac{3}{16}$ " $\frac{3}{32}$ "	3.02%
	Culm, " $\frac{3}{32}$-inch mesh	1.24%
Gas analyses—average of 5 samples taken at intervals during test	Carbonic acid gas	16.22%
	Oxygen	2.54%
	Carbonic oxide	Trace.

TABLE XVI.

Calculated Results of Heat Lost in Boiler Test Given in Table XV.

	Entering Furnace.	Pounds.	Waste Products.	Pounds.	Losses.	B. T. U.	Per Ct.
Fuel	Water (w)	1.55	Stack: Steam (x)	25.9505	x (1207.44+(540—400) × 0.48	33077.545	2.453
	Ash (p)	10.35	CO_2 (y)	299.9264	y (73.78 + (540—400) × 0.217)	31240.333	2.317
	Carbon (C)	84.19	CO (s)	. . . . .	s (4454.986+(540—400)×0.2479)	. . . . .	. . .
	Hydrogen (H)	2.01	Nitrogen (z)	873.3382	z (82.892 + (540—400)×0.2438)	102201.529	7.581
	Oxygen (k)	1.30	Oxygen (r)	30.5120	r (73.95 + (540—400) × 0.2175)	3185 452	.236
	Nitrogen (m)	.60	Hydrogen (L)	. . . . .	L (63259.06 + (540—400)×3.409)	. . . . .	. . .
	Total	100.00	Total	1229.7271	Total loss in stack	169704.859	12.590
Air	Oxygen (k_1)	263.4284	Ash Pit: Ash, pure (p)	10.3500	p (107.492+(500—500)×0.2443)	1112.542	.082
	Nitrogen	872.7382	Carbon in ash (q)	2.3770	q (14756.216 + (500—500) × 0.2414)	35075.525	2.601
	Water (w_1)	6.3105					
	Times theoretical quantity supplied (n)	1.1310					
			Total	12.7270	Total loss in stack and ash pit	205892.926	15.270

Total heat of fuel = C × 14650 + (H — $\frac{k}{8}$) × 62100 = 1348113.25 B. T. U. . . . . .

$\frac{\text{Heat utilized}}{\text{Total heat of fuel}}$ = 84.730 per cent. utilized.

$\frac{\text{Heat lost (except that due to radiation)}}{\text{Total heat of fuel}}$ = 15.270 per cent. lost.

Theoretical evaporation from and at 212° F. per pound of fuel . . . . . 13.97 pounds.
Actual " " " " " . . . . . 9.68 "
Total loss of heat . . . . . 30.708 per cent.
Loss by gases, water, and ashes . . . . . 15.270 "
Unknown losses . . . . . 15.438 "

given in Table IV. the results so as to obtain the amount of heat theoretically available for evaporating water and for radiation. (Table XVI.) As these boilers and their setting were very old

fashioned, and not economical, there was an enormous amount of radiating surface, so that the loss by radiation and unaccounted for, amounting to 15.44 per cent., was not excessive, considering that there were no special precautions taken, and that the test was made during the regular work of the colliery.

For comparison I give a table (XVII.) of boiler tests made at the Electrical Exhibition in Frankfurt-am-Main in 1891, in which the per cent. of heat utilized by the boiler, lost in escaping gases, lost in ash pit, and by radiation and unknown causes are given. These boilers were on exhibition, the tests were made by thoroughly competent experts (being competitive trials), and the firing done by expert firemen, yet under these circumstances the loss by radiation, &c., was from 5 to 13.6 per cent.

TABLE XVII.

Boiler Tests made at the Electrotechnical Exhibition held at "Frankfurt-am-Main" in 1891.*

	Willmann.	Dürr.	Herrmann & Schimmelbusch.	Göhrig & Leuchs.	Masch.—Bau, A. P. Nürnberg, D. R. P. Heine.	Schulz-Knaudt.	Schulz-Knaudt, D. R. P. Rinne.
	Water Tubes.		Upright Water Tubes.	Water Tubes.		Corrugated Single Fire Tube.	
	II.	III.	IV.	V.	VI.	I.	VII.
Per cent. of heat utilized by boiler	62.00	69.90	71.00	70.00	73.30	73.40	79.20
" " lost in escaping gases	22.00	22.60	20.80	17.70	17.70	16.10	13.50
" " " ash pit	2.40	2.00	.60	1.70	3.10	3.60	2.30
" " unaccountable, or radiation, &c.	13.60	5.50	7.60	10.60	5.90	6.90	5.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Times theoretical quantity of air supplied . . .	2.77	2.30	2.03	2.00	1.82	1.62	1.50
Temperature of stack gases (degrees Fahr.) .	507.2	595.4	622.4	545.9	590	597.2	550.4
Water gauge (with Siegert-Dürr's Instrument),	.33"	.33"	. . . .	.43"	.20"	. . . .	. . . .

* Zeitschrift des Vereines Deutscher Ingenieure, 1894, Band XXXVIII., page 732.

The analysis of the coal, of the gas, and of the ash, where proper arrangements have been made, or where there is a laboratory at the works is a comparatively inexpensive operation, compared with the great value of the results obtained.* The indications given by the analysis of the coal I consider of greater value than that of the calorimeter, although where analyses are made from time to time the calorimeter would be a very valuable adjunct. The calorimeter, under the most favorable circumstances, can only give the ash and the heat units developed by a given weight of coal. While two coals might give the same number of thermal units, one might be much more economical than the other on account of different percentages of water present. In the calorimeter test all the heat that goes to make steam is returned by the condensation of steam formed, whereas if the water is evaporated in the furnace it goes up the chimney and is lost. Where the same character of coal is treated, or where the tests are checked up from time to time by chemical analysis, data can be obtained which obviate the necessity of frequent chemical analyses; but, unless this is done, the calorimeter may lead to uncertain results, particularly if in burning the coal in the calorimeter any portion of the ash should be thrown out, as may happen in the Thompson calorimeter, or modifications of it, so that it would not be weighed. The work necessary to make a proper coal test, so far as obtaining the sample, crushing, weighing, and sieving, is the same for both kinds of tests, and after proper arrangements have been made the cost of the proximate analysis is comparatively small, and the time required to make one after the sample is weighed out does not exceed 1¼ hours, and during this time a man can make at least two; that is to say, at least two analyses can be carried on at the same time by the same person. The apparatus now used (†Hempel's

*The use of small sizes of anthracite coal for generating steam, President's address, New York meeting, 1893, before The American Society of Mechanical Engineers, by Eckley B. Coxe.

†Hempel's Gas Analysis, by L. M. Dennis; Select Methods in Chemical Analysis, by W. Crookes; Blair's Chemical Analysis of Iron; and Troilius' Notes on the Chemistry of Iron.

and Elliot's) for the analyses of stack gases are not very expensive; both can be made portable. The work and time required to make the analysis is not very great. It is not always necessary, when one is familiar with the working of the plant, to determine the carbonic oxide or hydrogen. In most cases the determination of the carbonic acid and oxygen is sufficient for practical purposes. Of course, where special study is being made of the condition of the plant, the other gases must be determined It is generally assumed that if the sum of the carbonic acid and oxygen amount to 19 or more by volume it is not worth while to look for carbonic oxide, hydrogen, or methane.

There is another advantage in making these analyses: They not only tell us what results we are getting and at what cost, but in most cases they tell us "why" it costs what it does; and my idea of a good engineer is a man who knows "how to do what is required, what it should cost, and why each item of the cost cannot be eliminated."

I would like to say a few words in regard to the methods of obtaining the furnace draft. There are three in general use—the chimney, the fan, and the steam jet. The advantage of the chimney is, first, that it allows the deleterious gases to escape at a point considerably above the surface, and, therefore, where they are the least likely to cause trouble. Secondly, when once properly built it can be maintained at little or no expense, and, if sufficiently large and high, the variations of temperature, &c., can be compensated for by regulating the damper. On the other hand, it is a very uneconomical heat engine* where the heat used can be saved, but where there are no means of utilizing it it is of little consequence how economical or uneconomical it is. It is always very difficult, in fact, I may almost say impossible, to obtain with it a sufficient blast to burn the smallest sizes of anthracite coal, which require a strong and concentrated draft. The steam jet has the advantage of costing

*On Chimney Draught, by Prof. B. W. Frazier, American Institute Mining Engineers, vol. X, page 249.

very little to put in and keep in repair. Its disadvantages are, first, it requires a very large amount of steam to run it; and, secondly, it introduces a large amount of water, or steam, into the fire, all of which has to be heated and carried up the chimney, and so far as it condenses in the ash pit has to be reconverted into steam. A still greater disadvantage is the fact that unless very carefully managed there is a large development of carbonic oxide, hydrogen, and marsh gas, due to disassociation of the water, which has a tendency to carry off a great deal of heat in the stack. The Engineering Department of the United States Navy made some experiments to determine the amount of water used by the steam blower in comparison to the amount of water evaporated, the results of which are given in Table XVIII.

TABLE XVIII.

Results of Experiments made at the New York Navy Yard to Determine the Best Form of Steam Jets for Producing Forced Draft in Launch Boilers.

Pounds of Water Evaporated.*	A.	B.	C.	D.	E.
In boiler making steam	463.8	540.0	361.25	528.5	545.00
In boiler supplying steam for blower	97.5	120.00	30.00	63.2	76.25
Per cent. of steam made as used by blower	21.20	20.70	8.30	12.00	14.00

* Per hour.

Taken from annual report of the Bureau of Steam Engineering, U. S. Navy, for 1890, pages 73–77.

In the case of Column A the steam jet was an annular orifice 1⅛ inches in diameter and 1-64 inch wide, and 24.3 pounds of coal per hour per square foot of grate surface was burned during the test.

Jet for B consisted of 33 holes, 1-32 of a inch in diameter, arranged in a circle of 1⅛ inches in diameter, and in the test 35.2 pounds of coal was burned per hour per square foot of grate surface.

Jet for C was a single hole, 1-16 inch in diameter and ⅛ inch long, from both ends of which it expands in a conical shape. In this test 14.2 pounds of coal were burned per hour per square foot of grate surface.

Jet for D was like C, except that the orifice was ⅛ inch in diameter. The quantity of coal burnt in this case was 26.9 pounds per square foot of grate surface per hour.

Jet for E was the same as D, except that the diameter of the orifice was 9-64 instead of ⅛ inch, and the quantity of coal burnt was 27.7 pounds per square foot of grate surface per hour.

It is very difficult to determine what is the amount of steam actually used in practice, as the men are generally very careless in the use of steam blowers, are inclined to turn on all the steam they can, and sometimes even ream out the holes in the jets, after the owner has determined how big they should be to produce the best results.

On April 11th, 1895, we made an analysis of the stack gases of two adjoining sets of boilers, the first set consisting of three cylinder boilers and two mud drums as described above, with feed-water heater in stack, the coal being burnt on a McClave grate with a steam jet blower; the other was the set described above with stoker and fan blower. Both used the same fuel and were fired by the same men, and the samples were taken at about the same time.

With the steam jet blower in the first case we obtained:

CO_2	8.20
CO	13.15
H	11.08
CH_4	2.00
O	0.30

With fan blower and stoker we obtained:

CO_2	16.80
O	1.70
CO	.40

These results are very remarkable, and I am perfectly willing to admit that we do not exactly understand them. The amount of carbonic oxide and hydrogen in the stack gases show an enormous loss, which seems almost impossible. But at the time (after dark) the sample was taken there was a very large flame issuing from the stack, in which the peculiar flame of carbonic oxide and hydrogen were both visible; so that there was no question as to the very unfavorable results obtained in this case by the use of the steam jet.

We have taken the question up seriously, and intend, if possible, to exhaust it; and if we do, or if we fail, I shall hereafter frankly state what we find. It may be observed that there was practically no oxygen in the stack gases, so that there was no chance for the carbonic oxide and hydrogen to burn.

It may be remarked that the analysis of the stack gases of the first case compares not unfavorably (considering the furnace as a gas producer) with the results given by Mr. Magnus Troilius in his paper on "The Analysis of Furnace Gases" read before the American Institute of Mining Engineers, Boston Meeting, February, 1883, where he finds in two samples taken from gas producers:—

CO_2	7.50	8.00
CO	16.00	15.50
H	15.30	14.90
CH_4	1.90	

The fan is more expensive to install and may cost more to keep in order, but where the arrangements can be made to utilize the heat in the stack gases, it is more economical so far as heat units used are concerned. It has one great advantage—it is possible to at all times obtain the exact blast necessary to produce the best results in the furnace, which is very important.

I am of the opinion, though I advance it with some reservations, that particularly for the finer anthracites the best results will be obtained by blowing the air by means of a fan through the coal, and, either by a suction fan or chimney, drawing the furnace gases through the boiler, &c., in such a way that there is practically no plenum or vacuum in the furnace or under boiler—or rather a very slight plenum, sufficient to prevent the inflow of any air

where it is not wanted. In what precedes I have not discussed the question of testing the boiler by means of weighing coal, weighing the ash, and weighing the water, as tests are ordinarily made. While nobody appreciates more highly than I do the advantage of such tests, for in our investigations we often make them, I wish to call attention to the fact that the analysis of the coal, the ash, and stack gases, and the determination of the stack and ash temperatures, give us a means of quickly and cheaply determining practically how much water we are evaporating per pound of coal, when you have once thoroughly tested your apparatus and checked up the results obtained by analysis with the results obtained by the ordinary test. There are several advantages in this manner of testing. We in this way keep track of the coal we are buying, and every large purchaser of coal ought, from time to time, to analyze it. Those wishing to look into this subject more fully are referred to my paper on the subject, mentioned above. The analysis of the ash is not only important for the test, but is very valuable from another point of view. Every manufacturer using large quantities of coal should know how much money he is throwing away in his ash heap. Stack temperatures, if they are below 800° (and they always should be), can easily be determined by the mercurial pyrometer, which can be done in a few minutes by a person of ordinary intelligence, who knows enough to read a thermometer. The analyses of the stack gases are valuable for the tests, and for understanding how the coal is being burned. But the great advantage of this system of keeping track of what you are doing with your plant is, it can be and should be done when the boilers are being fired in the ordinary way and by the ordinary men. The taking of the samples of the coal and ash does not in any way interfere with the operation of the plant, nor does the taking of the sample of the gases and the temperature of the stack; it can be done at any time and as often as you please. If your man is firing badly, or better at one time than another, the composition of the gases will show it; if your boiler tubes are coated, either inside or outside, your stack temperatures will give you a very good indication that you

ought to clean them, provided that you systematically watch what is going on. At the risk of repeating some things I have already said, I will give a few thoughts which have impressed themselves upon my mind in writing this paper, and then proceed to the description of the stoker.

It seems to me, coal should be kept as dry as possible; not exposed to the air, if it can conveniently be avoided. Where coal has been exposed to the air and wet it is advisable to get it in the boiler house and allow it to dry out as much as possible before using it. It should be handled carefully so as to avoid breakage. The boiler plant should be well covered in, so as to prevent water, snow, or ice from getting upon it. The boiler house should be kept as warm as it can be and be comfortable, not, of course, by heating the building with steam or fuel, but by so constructing it that there will be a minimum loss by radiation from it, and should be as free from currents of air as possible. No water, moisture, or steam should be allowed to get into the coal, even under a patent, if it can be avoided. The temperature of the stack gases should be kept as low as possible by having the boiler and the feed-water heater or economizer so arranged as to abstract all the heat possible.

In this connection it may be well to insist upon the importance of keeping the heating surfaces clean, particularly when forced draught and small coal are used, as in that case there is much more flue dust deposited, and the efficiency of a boiler diminishes very rapidly as the heating surfaces become coated.

While it is a self-evident proposition that the lower the temperature at which the stack gases are discharged into the atmosphere, under the same circumstances, the greater must be the amount of water evaporated per pound of fuel, yet it is not so certain that we understand the best method of reducing these temperatures. The heated gases from the furnace come first in contact with the boiler, and are generally discharged into the stack after leaving the boiler. Under these circumstances their temperature must be above that necessary to generate steam at the pressure maintained in the boiler—the higher the pressure of steam the higher must be the temperature at which

the stack gases leave the boiler. If, however, an effort is made to reduce their temperature to a minimum, a large portion of the heating surface of the boiler nearest the stack will evaporate very little water, the difference in the temperature between the gases on one side of the iron plates and the water on the other being so slight. In the more modern plants the gases, after having passed through the boiler, are used to heat the feed water, which, entering the feed-water heater or economizer at a very much lower temperature than the steam, is able to absorb heat from the gases, which the boiler is not.

A still further economy is ideally possible by utilizing a portion of the remaining heat of the gases to warm the air which is taken into the ashpit. While I am not really an expert in this matter, yet I venture to make a few suggestions as to what appears to be the line in which efforts for further economy should be made. I would try to have the highest possible temperature of combustion in the furnace, protecting the boiler and furnace from the direct radiation of the fire as well as I could, and would allow the gases to escape from the boiler at the highest temperature, consistent with the heat contained in them above the temperature which would be of use for this purpose, all the rest being absorbed by the feed water; that is to say, if I were feeding 100 pounds of water a minute, I would try to increase the temperature of the gases, leaving the boiler, until the thermal units in them were about what could be utilized in heating the feed water, to the temperature at which it could be placed in the boiler, without allowing the temperature of the gases escaping from the feed-water heater or economizer to be above that at which they could do useful work. My reason for this is the following: The higher the temperature at which the gases pass from the boiler the greater will be the evaporation per square foot of heating surface, and also the higher the temperature of the feed water pumped into the boiler will be. Consequently the greater the evaporation of water per dollar invested in the boiler. To obtain the best results, the feed-water heater should be arranged so that the water passes through the heater in the opposite direction to

the gases; that is, the hottest gases should come in contact with the hottest water, and as they are cooled they should come in contact with the cooler water. If the gases leaving the feed-water heater were allowed to pass either around the outside or through a series of metal pipes of sufficient length, and the air supplied to the furnace was carried through these pipes or around them, much of the heat still contained in these gases above the temperature of the atmosphere might be abstracted and returned to the furnace, and the loss of heat from the stack gases be largely diminished. There are two objections to this, the cost of the apparatus and its maintenance; and as there would be no heat available for chimney draft, it would be necessary to have a suction fan to draw the gases out or to have a strong forcing fan. While it is probable that in most cases it would not pay to utilize the heat of the escaping gases in this way, yet where coal is very expensive it is possible that satisfactory results might be obtained, although Mr. Hoadley in his paper above referred to, in which he discusses these questions very fully and ably, does not seem to hold out very great hopes.

The temperature of combustion in the furnace should be as high and as even as possible if we wish to obtain the greatest efficiency with a given plant.

Our grandmothers always put the kettle on the hottest part of the fire when they wanted to boil the most water in a given time. In managing the fire we should always arrange to have an excess of air, but it should be as small as possible consistent with thoroughly burning the carbonic oxide, hydrogen, and marsh gas; for if you have 3 per cent. of free oxygen, 17 per cent. of carbonic acid, and with it 80 per cent. of nitrogen and your stack temperature is 500°, the heat lost is 12.27 per cent. But if you have 1 per cent. of carbonic oxide, 3 per cent of free oxygen, and 16½ per cent. of carbonic acid in the stack gases at 500°, the heat lost is 16.12 per cent.

The ashes should be as cool as possible when removed from the ash pit and contain a minimum of carbon. We should be uniformly economical. The natural tendency is to be very eco-

nomical in certain things, perhaps even parsimonious, and to neglect or pay little attention to others of equal importance. One man will be very particular about keeping the temperature of his stack low and pay no attention whatever to the composition of the stack gases. Another will be very careful about the composition of his ash and put water on his coal before he fires it, or at least allow nature to do it for him by making no provision to protect the fuel from the weather.

I am perfectly aware that this paper is incomplete and in many respects inconclusive. The reason is very simple—I do not know enough to settle any of the vital questions. The importance of the subject has grown upon me while writing this paper, and the most that I can hope is to raise one or two important issues.

I shall now proceed to the second part of my paper, which is the description of a furnace with which I have been experimenting, and in which I have sought to place the fuel in the conditions which a series of experiments made by us at Drifton seem to indicate to be those in which the smaller sizes of anthracite coal can best be burnt. Some four years ago the State of Pennsylvania appointed a commission, of which I was one, to investigate the question of the utilization of the waste products of our anthracite mines. One of the most important problems we had was what could be done with the small sizes, of which large quantities at that time were being thrown away? After satisfying myself that my knowledge of the question was not of such a character as to be of much value, I started to look up the literature on the subject, and found that I could get but little aid from it. So I began a series of experiments in burning the the smaller sizes of anthracite coal with both a fan and steam jet blast, the ordinary natural draft not being sufficiently strong for the purpose.* These experiments were made in a furnace 3 feet

* "Commonwealth of Pennsylvania. Report of Commission appointed to Investigate the Waste of Coal Mining, with the View to the Utilizing of the Waste." The Commission was composed of Eckley B. Coxe, Drifton, Pa.; Heber S. Thompson, Pottsville, Pa.; William Griffith, Scranton, Pa. Report published in May, 1893. Philadelphia: Allen, Lane & Scott's Printing House, 229–233 South Fifth Street.

long, 2 feet wide on grates of various kinds. The coal and ash were in all cases analyzed, and both were weighed. These experiments were made by my assistant, Mr. John R. Wagner, who has been of great assistance to me in the preparation of this paper.

A portion of what follows is taken from a paper* read by me at the Chicago meeting of the International Engineering Congress in August, 1893 :—

"A series of careful experiments were made with a forced draught, obtained in one case by a fan and in the other by a steam jet, which showed—

"*First.*—That the ashes produced by a steam jet were never as low in carbon as those produced by the fan ; that is, an appreciable larger per cent. of the carbon was utilized by the fan blast. This appears to be due to the fact that when the carbon in the ash over the grate is reduced to a certain point the steam dampens it somewhat, and it ceases to burn sooner than it does when dry air only is blown through it.

"*Second.*—That with the fan blast the rate of combustion per square foot per hour is greater than with the steam jet.

" *Third.*—It was found that where a bed of coal was ignited and burned out the percentage of carbon in the ash is much less than where coal is successively added to the burning mass. In practice it is not generally possible to allow the bed to burn out sufficiently before adding fresh coal ; the result is a damping down of the fire, which causes the ash to cease burning sooner than it would do if there were no reduction of temperature and checking of the draught due to the adding of the coal.

" *Fourth.*—There seems to be no doubt that the introduction of steam into the ash pit decreases very materially the tendency of the coal to clinker on the grate in comparison with the fan blast or natural draught. It also changes the color,

* " A furnace with automatic stoker, traveling grate, and variable blast, intended expressly for the burning of small anthracite coals." Transaction of the American Institute of Mining Engineers, vol. XXII.

volume, and character of the flame, and, owing to the producer action, increases the distance that the flame extends beyond the bridge wall. In many cases it is not practical, or, at least, it is very difficult to fire the smaller sizes of coal without the steam jet on account of the clinkering. This effect of steam on clinkering is probably due to the fact that the steam, to a certain extent, moistens the ash close to the grate and prevents the ash from reaching there as high a temperature as it would with dry air. It is also probable that the decomposition of the steam into carbonic oxide and hydrogen, which takes place to a certain extent, and which, of course, is accompanied by a reduction of temperature, tends to prevent clinkering. The decomposition of the steam, accompanied by the formation of carbonic oxide and hydrogen, will probably account for the difference in the flame referred to.

"*Fifth.*—A careful study of the burning of culm, that is, the burning of small coals with more or less dust in them, in these and other experiments, seemed to show that in almost all cases it is accompanied by a very high percentage of carbon in the ash, which analysis showed, in some cases, reached 58 per cent. Unless special precautions are taken to prevent it, a large portion of the fine coal runs down through the grate. When the culm gets red hot it acts almost like dry sand and works its way into the ash pit, thus increasing largely the percentage of carbon. Where coal has to be transported any distance, the value of the culm at the mines being very small, it is probable, from the investigations made, that it would be cheaper to remove the dust and transport only the larger coal.

"*Sixth.*—It has been found that the percentage of iron pyrites, which occurs to a greater or less extent in all coals, increases very rapidly with the smallness of the coal. This is due to the fact that the iron pyrites occur generally in thin layers or in incrustations on the coal. These thin layers are broken off and pulverized in the preparation and handling of the coal, and are therefore found to a much greater extent in the very small coal. It is, of course, well known that the presence of iron pyrites in

fuel is very undesirable, as it generates sulphurous anhydride and has a tendency to destroy the grates or other iron work around the boilers, besides, in many cases, increasing the tendency to clinker.

"*Seventh.*—That while the fan blast produces the best ash and gives a more perfect and greater rate of combustion, yet in many cases it is more advantageous to use the steam blower on account of the clinkering, which may cause very serious trouble. In certain localities, particularly in cities, the noise of the steam blower is sometimes a disadvantage.

"*Eighth.*—While it is not positively demonstrated, it is thought that the question of mixing small coals from different veins or different localities is a matter of importance. It would appear that sometimes two coals, each of which, when burned separately, give reasonably satisfactory results, when mixed together clinker and give trouble, probably because the ash of the combined coals forms a much more fusible silicate than either of the ashes separately.

"*Ninth.*—It would seem that the combustion of the small anthracite is more perfect when the coal remains undisturbed, or as nearly as possible in the condition in which it was put in the fire, instead of being turned over so that the partially consumed and the unconsumed coal are mixed together."

Our experiments were not sufficiently extended and exhaustive to justify us in asserting that all these conclusions are absolutely true, but only that they seem to us probable.

Another point referred to in the same report, and which our further experience seems to confirm, is the fact that the temperature developed by the burning of the smaller coals decreases with the size of the coal; this naturally involves a larger heating surface in the boiler in order to develop the same number of horse power; that is to say, if you are burning pea coal and obtaining one-horse power for every nine square feet of heating surface, you would probably require from 20 to 25 per cent. more heating surface if you are using No. 3 buckwheat, although you may be evaporating practically the same amount of water per pound of combustible.

It is also stated in the paper that it is possible that the best results in burning these small coals may be obtained by using a blower under the grate and a suction apparatus in the stack. This statement should be modified, as the following is probably a more correct statement of the case: Where the passage of the gases through the boiler furnace to the stack is free and unimpeded, and the stack reasonably high, it may be necessary to check the draught by a damper near the outlet; while should the furnace and boiler be so constructed that the gases travel a long distance and are more or less seriously impeded in their flow to the stack, which is not very high, it may be necessary to put some suction apparatus in the stack. In other words, there is a certain speed for every boiler plant which the gases should have in passing through in order to obtain the most economical results, and some device should be adopted to maintain it.

Having determined, in a general way, what seemed to me the proper conditions for burning small anthracite economically, I started to design a furnace which would, as far as possible, fulfill the required conditions, which were:—

1st. To ignite the coal and burn it up without mixing it with fresh fuel; that is, that fresh fuel would not be added to the already partially consumed coal.

2d. To have the furnace so arranged that the combustion should be continuous and uniform; that is to say, that when the furnace was in use the condition of the fire would be practically the same at any hour of any day of any week of the year.

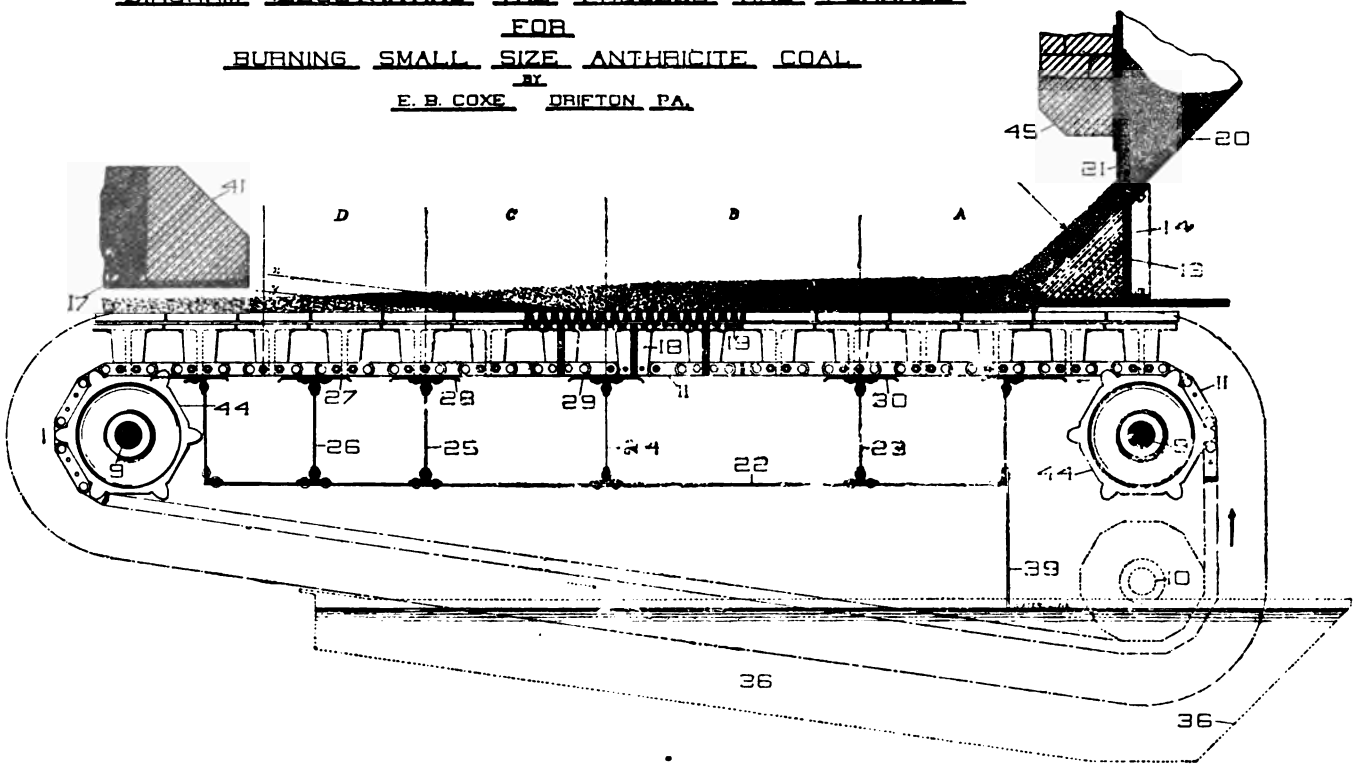
3d. To make the work of firing as easy as possible, so that a minimum number of firemen would be employed, and that the whole operation of the furnace would be controlled by an intelligent man who would have more use for his brains than for his muscles. The idea being that in a large and complete plant the coal would be brought from the source of supply by elevators or drags, and fed to the furnace without hand labor, and that the ashes would be carried to or dumped into a pocket where they could be easily loaded into cars in the same way. No pokers, slice bars, or other similar tools should be needed.

PLATE II.

DIAGRAM ILLUSTRATING THE PROCESS AND FURNACE FOR BURNING SMALL SIZE ANTHRACITE COAL

BY

E. B. COXE DRIFTON PA.



The diagram in plate II., which I shall use for the general description of the grate, is not an exact representation of the furnace as built, it being intended more especially to explain the principle of its action.

The furnace consists essentially of a traveling grate moving from the right toward the left. The coal which is brought to the hopper 20 by a drag, spout, or any other convenient method, feeds down by gravity over the fire brick 14 onto the traveling grate. The coal is carried slowly at the rate of from 3½ to 5 feet per hour toward the other end. In the beginning of the operation the coal on the right-hand side of the furnace is ignited, the other part being covered with ashes or partially consumed coal. After the furnace is heated the fire brick 14, which we call the "ignition brick," becomes hot, and the coal, passing down under the regulating gate 21, becomes gradually heated, and by the time it reaches the foot of the ignition brick is incandescent. In some cases the coal becomes hot enough to ignite soon after it passes the regulating gate 21. Under the grate there are a number of chambers made of sheet iron, which are closed on all sides except on top. The blast from the fan which is used to furnish the air is blown into the large air chamber, which is the second one from the right. These air chambers, are open on top, but the partitions are covered by plates 27, 28, 29, and 30. These plates are of such width that no matter what may be the position of the grate bars 18, there is always one resting upon this plate, so that the air cannot pass from one chamber to another except by leakage along the bar. The result of this arrangement is that if we are blowing into the large air chamber with a pressure, say, of 1 inch water-gauge, the pressure in the next air chamber to the left would be about ¾ inch, the next to that ½ inch, and the next to that ¼ inch. Of course these figures are not strictly correct and are used merely for the purpose of illustrating, as I am now describing only the general principle of the apparatus. The pressure in the air chamber to the right would be, say, ¾ inch. The result of this state of affairs is, that the coal when it arrives on the grate is

subjected to a pressure of blast sufficient to ignite it, but not too strong to impede ignition.

In order to regulate exactly the pressure of the air in each of the compartments, the partitions are provided with registers, by the simple opening and closing of which the pressure in the air chambers can be varied to suit the conditions.

As the thoroughly ignited coal passes slowly over the second compartment (where the air pressure is a maximum) it burns briskly, and then slowly passes over the third compartment, where the air pressure is less and better suited to the combustion of the thinner layer of partly consumed coal, the bed continues to diminish in carbon, and to be subjected to less blast, until, finally, the hot ashes are cooled off (before being dumped) by a very gentle current of air, which is heated and mingles with the carbonic oxide produced in the zone of intense combustion B and converts it into carbonic acid, the object being to subject the coal as soon as it arrives on the grate to a pressure of blast which is the proper one to ignite it; then burn it with a blast as strong as will produce good combustion, and as the carbon is eliminated and the thickness of the bed becomes smaller to diminish the blast to correspond to these conditions. The mass of coal remains all the time in practically the same position and condition in which it was placed on the grate, except so far as altered by the combustion. It is evident that there would be a tendency of the air to pass out between the brick rest 13 and the top of the grate bars 19, which have no coal on them, and if no provision was made to prevent it the air would pass under the air chamber along the line of travel of the grate and enter the furnace through the ash exit at 17, thus forcing a large excess of air into the space under the boiler and causing a loss in two ways: First, in the power necessary to furnish the air, and, second, in the heat carried off by the surplus of air going out the stack. This is avoided by having the returning line of grate pass into a water pan 36. By means of the partition 39, which passes down below the surface of the water, a water seal is obtained which absolutely cuts off all connection between

the front and back ends of the lower portion of the furnace along the line of travel of the grate. The ash pit, which is practically the part to the left of the plate 39, is closed by a door out of which the ashes are taken, and the front end of the boiler is closed by a sheet iron casing, which passes down into the water in the water pan, thereby preventing the air from passing out between the brick rest 13 and the grate bars into the free air. There is space enough between the extreme right-hand end of the water pan and the vertical wall of the casing to allow any ashes or dirt that may accumulate in the water pan to be taken out very easily.

From this brief description the continuous action of the furnace can be easily understood. The coal passing continuously down from the ignition brick is ignited gradually, burned out, and the ashes are carried off or dumped by the grate bars as they descend and become vertical.

The coal ignites and burns more from the bottom, that is, the first thin layer of complete ash forms on the bottom and gradually becomes thicker until it reaches to the top. At first the ash is very hot, but the gentle current of air passing through it gradually cools it off, and when it is dumped into the ash pit it is comparatively cool. The shaded portion beginning in C and extending into D represents the gradual formation of the ash, and the part to the left of that shows the ash practically cooled or cooling.

A certain portion of air from which the oxygen is not removed passes through and cools the ash, but in the first sections of the bed of fuel near A a certain amount of carbonic oxide is formed, due to the fact that the amount of air blown through is not sufficient to properly consume all the carbon, and the incandescent carbon will always decompose a portion of the carbonic acid, the carbonic acid forming carbonic oxide very much as in gas producers. This carbonic oxide is burned in the furnace by the air which has passed through the ash. Our experiments have shown us that if we allow the gases to pass through the furnace with a velocity that will permit the carbonic oxide

to burn completely before reaching the parts of the furnace too cool for the combustion to take place, we get a better result, and in one of our plants we have found an increase in efficiency and economy by putting a damper in the stack and checking the flow of gases. Of course, there is a velocity for each furnace above or below which you have less economy and less efficiency, provided you are burning a certain number of pounds of coal per hour.

Having thus briefly described the process, I will now give some details as to the construction of the grate and the method of placing it under the boilers.

One of the first difficulties we encountered in our experiments with the traveling grate was the fact that if we had a fire brick side wall there would be a tendency to form clinker along it. This clinker would retard the coal that should be carried forward, and have a tendency to break up the fire near the walls and allow the air to escape, giving considerable trouble. This has been avoided by making the sides of a hollow cast-iron bar (called the water back), No. 15, plate III. We now use a water back made of wrought-iron pipe formed to the proper shape under a steam hammer. The water is fed in at the front end, and flows out at the top of the other end.

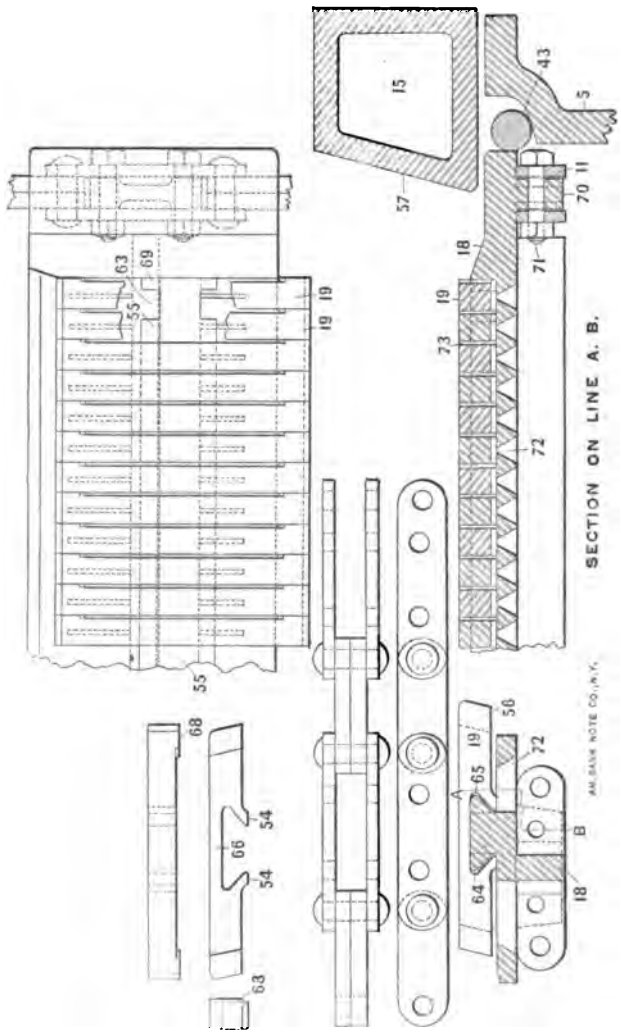
Our experiments with various boilers show us that if we pass the amount of feed water which is necessary to supply the boilers through this water back, on each side, the water leaves it at a temperature of 110° to 150°. This goes directly to the feed pump, and the heat is all utilized. We also found that the coal had a tendency to burn a little more rapidly along the water backs, so that the layer of partially consumed coal became thinner there more quickly than in the centre, thus allowing a too free passage to the air at that point. This has been avoided in two ways. First, by having no air spaces in the grate bar at that point; second, by making the water back narrower at the top than at the bottom, which gives a larger quantity of coal to be consumed along the water back, so that, if anything, the tendency is to have the layer of ashes there a

little thicker than in the centre. It is also important that there should be practically a tight joint between the end of the bar and the side along which it slides. This is accomplished (as shown on plate III.) by having a casting, 5, a portion of which, forming an inclined plane, makes the fixed side. The joint is made by round bars of iron cut in sections about 1 foot long. This bar of iron rests on the inclined plane and rolls against the end of the bar, 18. If one bar, 18, protrudes more than another, it simply pushes this iron bar, 43, back; if it recedes, the iron bar follows it down. If the bars, 43, were all cut off square at their ends, the moving grate bars, if not exactly of the same length, might catch upon them if one projected a little beyond the other; the bars 43 are, therefore, rounded off at the end. We have since avoided this difficulty by allowing the water back to project 2 inches over the ends of the moving bars, which are solid castings where thus covered, and we do not now use the round bars.

The grate (see plate III.) is formed of two parts; the lower, 18, which is T-shaped, consisting of the vertical rib and the horizontal plate. The horizontal plate is perforated with a number of conical-shaped holes, wider at the bottom than at the top, or is cast with oblong openings as is shown in the drawing, and it has on its upper surface a dovetailed rib, 55. At each end is a lug, which fits into the chain 11. There are two holes cast in the bar and two holes drilled in the alternate or long links of the chain, and by means of two bolts each end of the bar is fastened to the chains. The upper part of the bar, 19, consists of sectional bars about 7¾ inches long by ⅝ inches wide, provided with projections, 68; this leaves an air space of about ⅛ inch between each pair of bars. The construction and simplicity of the small upper or sectional bars, 19, is readily understood from plate III., from the upper right-hand view of which the manner of securing them to the main or carrying bars is shown.

At the right-hand end of the dovetailed rib, 55, is a slot, 63, dovetailed at the bottom, which will allow the lower part, 54, of

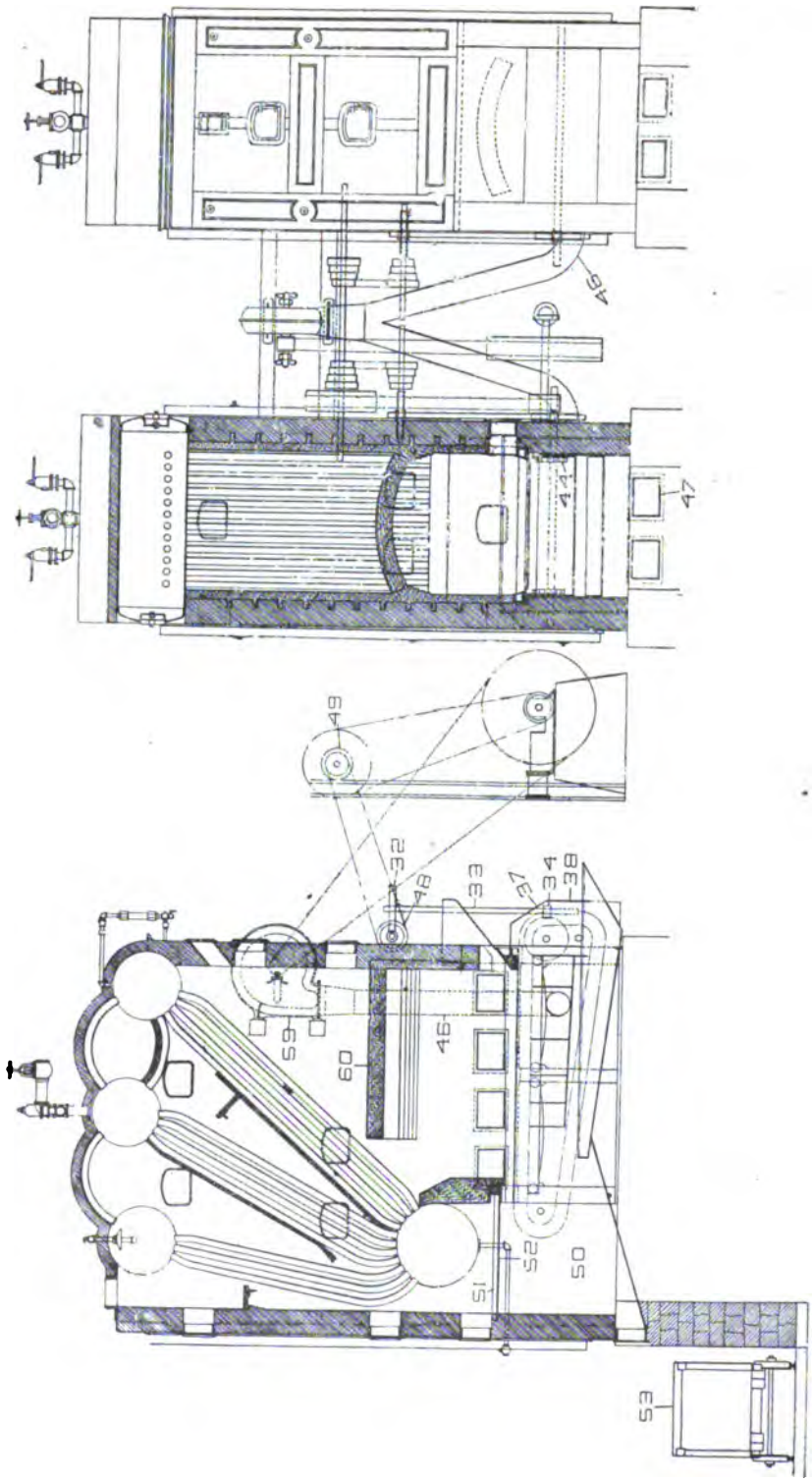
PLATE III.



the small bars to drop into the position on the main bar; the bar is then moved laterally to the left and another dropped in the slot and moved along to the left, until the whole carrying bar is filled. To keep these small bars from dropping out of the slot in which they enter, the bars are moved to the right, when the last bar is held by the partial dovetail, 69, and the second from the right is held on by the dovetail, 55, to the left of the slot, 63.

These bars must not be placed tightly against each other as they expand when heated, so that when the proper number of sectional bars (called "keys") have been put on and they are crowded together the slot is entirely exposed. A dovetailed piece (made of cast iron), which fills up the opening so as to make the piece 55 continuous through its whole length, is inserted, and the bars are separated so as to be distributed uniformly through the whole length of the long bar which they fill loosely, then as there is no push towards the left hand more than towards the right, and since it requires a large force to move the extreme right-hand bar to the left, as it has to push all the others, there is no tendency for it to drop out. This method of fastening the bars is very simple and effective. To remove an imperfect bar, a blow of a hammer on the thin part, 66, will allow the parts to be removed from the carrying bar, when the others are pushed up and another inserted at the end, as above explained. The important feature in this sectional bar, or key, is its small dimensions, the distribution of the metal, its ability to expand and move sideways up and down and in the direction of the movement of the chain at changes of position of the carrying bar, which occur principally at the ends of the furnace. This tends to keep the grate free from ashes. The bar, 19, fits loosely, at 64 and 65, over the dovetail 55. It will be observed that 19 projects a little over 18, on the right-hand side, and that 18 projects beyond 19 on the left-hand side, so that when two complete bars are together they overlap and close the joints so that no coal can fall through. By constructing the grate in this way, the only parts exposed to the heat of the fire are the small sectional bars, 19, on top.

PLATE IV.



The main or carrying bar, 18, is pretty well protected from the intense heat, does not warp or twist, and shows, so far, no sign of giving out; this is very important. The expansion is also taken care of.

In addition we now core holes all across the bar through the dovetail 55 and make the top of this dovetail concave, so that there is a free passage of air through the slot between the bars in the middle where they are thinnest, and a chance is given for any ash forming there to drop out.

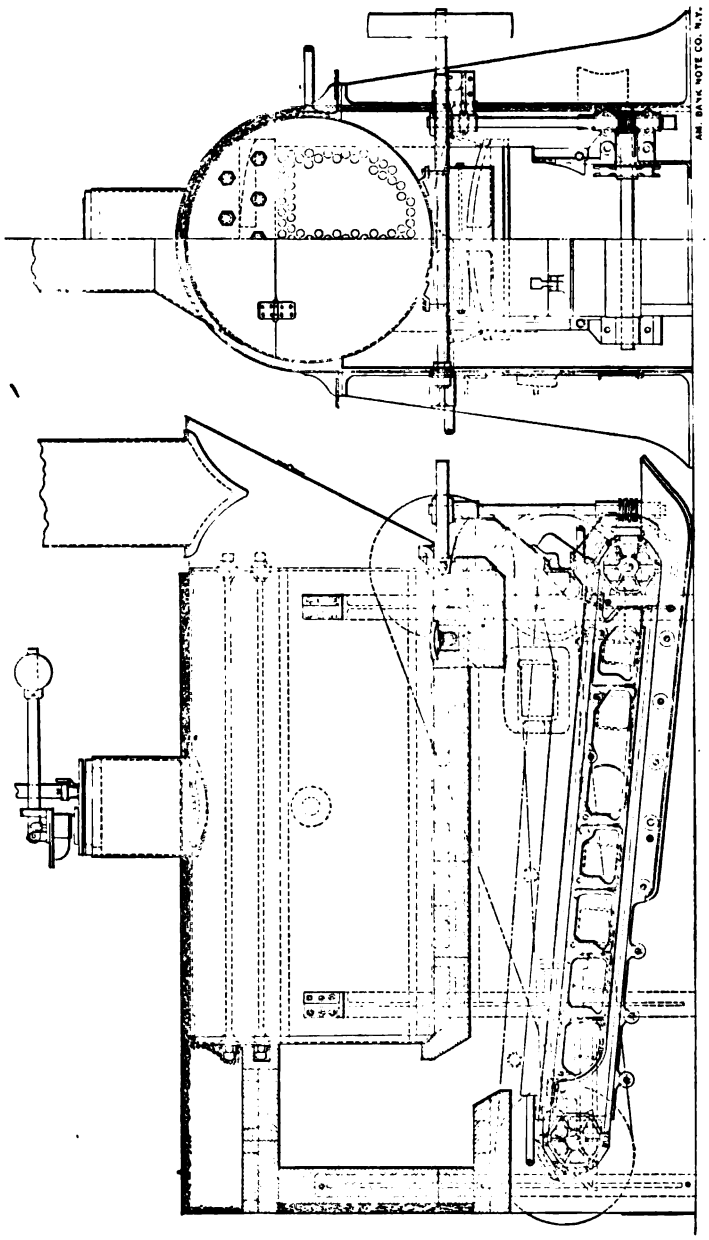
The construction of the chain (11) can be easily understood by the inspection of Plate III. The two chains when the stoker was built, as shown in Plate II., passed over three pairs of sprocket wheels on three shafts; but in the more recently-constructed stokers there are only two pairs of sprocket wheels. In order to prevent any sagging of the bed of coal and to reduce the friction, the chains are carried on little wheels both above and below. If there is not a sufficient number on the upper run the top of the bed of coal becomes a waved surface and the fire is more or less disturbed.

The arrangement is shown very distinctly in Plate VI., where these wheels are indicated by the figure 12. The sprocket wheels at the inlet end are the drivers, and the shaft on which they are keyed is driven by two sets of worm-wheel gears, as is shown on Plates IV. and V., where Figs. 32 and 34 represent the worm gear.

As the speed of the grate is very slow—from 3 to 7 feet per hour—the sprocket wheel does not make more than one revolution per hour, and often less, the result of which is that very little power is required to drive the stoker, but the revolutions of the driving shaft have to be very much reduced by some intermediate mechanism.

We have substituted for the two sets of worm gears which take up a good deal of room, becomes more or less clogged with dirt, and may be easily broken if anything should get in the teeth, the reducing mechanism shown on Plate VII., which we find very satisfactory. The shaft S, which is 3½ inches in diameter,

PLATE V.



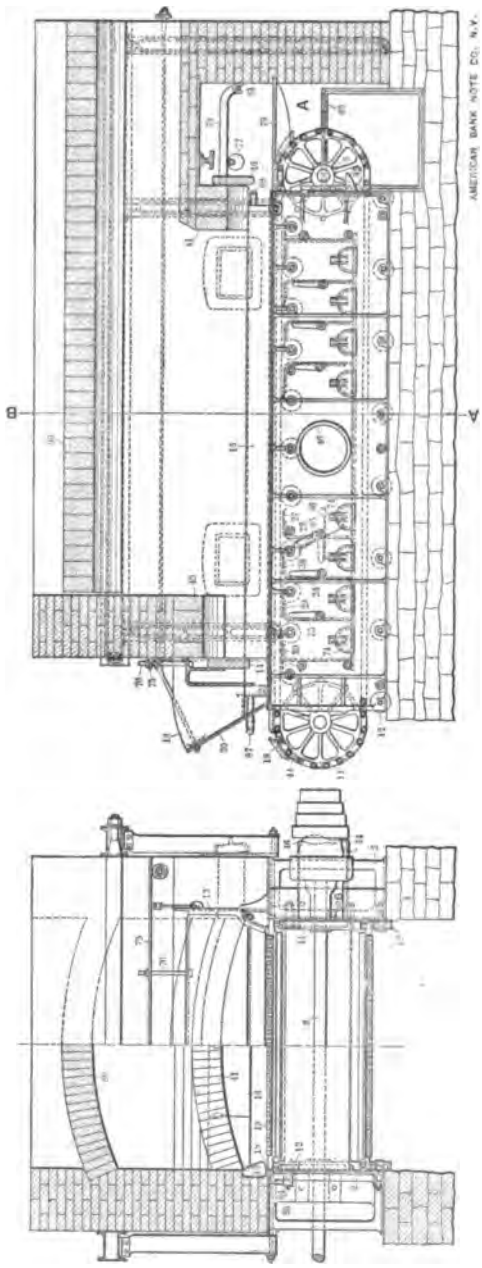
is the one upon which the sprocket wheels to drive the grate are keyed. For a certain distance, S″, it is reduced to 3¼ inches, and for another distance, S‴, to 2½ inches. The cone pulley by which it is driven is shown at the right hand. This pulley is keyed on a sleeve running on S‴, and at the end, K′, there is an eccentric which is made out of the same piece as the sleeve. Upon the latter there is a spur wheel, G_6, with 44 teeth. Upon the part S″ of the shaft is another eccentric sleeve carrying on the right-hand side an annular gear with 51 teeth. Upon the second eccentric is another cog wheel with 64 teeth, and keyed on the shaft S is another annular gear with 71 teeth. D is a portion of the pedestal, and remains fixed; to it is bolted the cover M, which is also fixed. On the inside of this cover are two annular gears, one with 70 and the other with 50 teeth, which do not revolve, but mesh with one-half of the spur wheels. As the spur wheels revolve they mesh with both the fixed and movable gears. As there is one more tooth in the first movable annular gear, it falls back one tooth every time the cone pulley makes a revolution, so that 51 revolutions of the cone pulley cause 1 revolution of the second eccentric K. When this second eccentric makes 71 revolutions, the shaft S makes 1 revotion, so that when the cone pulley has made 3621 revolutions the shaft S has made 1. All the gearing is inclosed in the casing, which is partially filled with oil, so that the wheels run continuously in oil and are not exposed to any dust or dirt that may be in the boiler house. This very simple mechanism enables us to belt directly from any ordinary line shaft, and simplifies very much the shafting required.

The reducing mechanism is the invention of Mr. F. H. Richards, of Hartford, Conn.

In order to show what progress we are making I give here a list of the machines we have built.

There are six stokers 6 feet wide running under 3 Stirling boilers, and four more are being erected at the same plant. There are two 7½ feet wide running under two Babcock & Wilcox boilers, and one stoker 4 feet wide under a return tubular

PLATE VI.



boiler, and another 4 feet wide has just been completed to heat the feed water for a large plant of boilers. In addition, at the works controlled by our companies, we have four 6-foot stokers under Stirling boilers, three 3-foot stokers under tubular boilers (Plate V.), six 7½ feet wide under the old-fashioned cylinder boilers as described above, six 6-foot stokers in front of large tubular boilers 90 inches in diameter, 15 feet long with 266 2½-inch tubes, two 7½ feet wide for similar boilers in process of erection, and one 4 feet wide under cylinder boilers, making in all 36 either running or nearly ready to run.

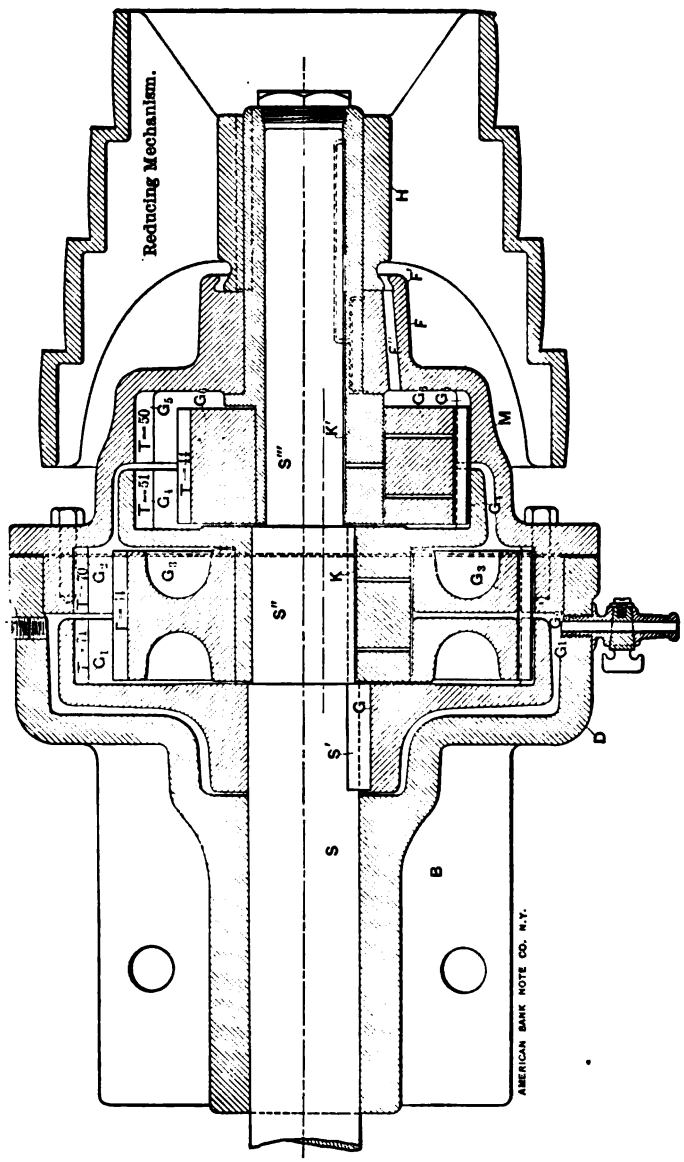
The first of these stokers was erected in November, 1892, and we have been building them continuously ever since. Plate IV. gives a side and a transverse elevation of a Stirling boiler plant at No. 3 colliery, Oneida, Schuylkill County, Pa., and shows the manner in which the stoker is placed under the boiler and the arrangement for supplying air to the furnace. This plant has been running continuously since May, 1893. Plate V. shows a semi-portable boiler with stoker, of which there are three in operation. It is a tubular boiler, the under part of which is protected from the direct radiation by a fire brick arch, which, while keeping this part of the boiler hot, prevents its being burnt in case there is scale or mud in the boiler. Plate VI. represents the most modern form of stoker, being the one we are now erecting and expect to start in two or three weeks. Plate VIII. shows what we now consider the best way of applying the stoker to our large horizontal tubular boilers, which are 90 inches in diameter and have 266 tubes 2½ inches in diameter and carry 150 pounds of steam. It will be observed that in this case there is very little radiation except after the gases have left the boiler. This plant will be erected at once.

As you would no doubt suspect, there were many defects in the original construction of the stoker, which the practical use of it brought to light. To these I will now refer.

The water back was originally constructed of cast iron, and when there were no defects in the casting and when nobody dropped it, or a piece of iron upon it, on its way from the shop

to its place in the brick wall, it was very satisfactory. If any accident happened to it the water back was generally spoiled. After some little experimenting we found that we could make them out of wrought-iron pipe, forming them under the steam hammer, and when thus made they are very satisfactory. The heat in the furnace, when it is properly constructed, is very great, being sufficient to melt cast iron in a crucible, and in consequence it was only after a long series of experiments that we obtained a grate bar that would stand the work. We had no trouble with the clinkering. The coal next to the bars does not clinker. It forms a thin bed of unfused ash between the bar and the clinker, so that when the ashes reach the back end they dump without trouble. The action of this thin bed of ash is very much like the butter the cook puts on a tin plate when making a pie. The great point in the construction of the bars is to have the keys very loose, so that they can expand freely in all directions. If they are put on so as to be immovable they will very soon be affected by the fire. Although the chain constructed, as seen in Plate III., has been very satisfactory, yet we are now making a new one out of steel drop forgings, the pins being carefully turned and all the holes drilled. While the chain will not be very much heavier, it will be at least twice as strong, and will be so constructed that 10 or 15 feet of it will always be of the same length; it will have only half as many joints as the old style. As originally constructed, the registers between the different compartments of the air pan was made by cutting holes in the partitions and having pieces of sheet iron with similar holes to slide in front of them, so as to close any part or the whole of the orifices; we have found it much more satisfactory, however, to make these openings the whole width and close them by pieces of sheet iron revolving on a shaft fastened to the middle of the plate, like the damper in a stove pipe. As originally constructed, and as shown in the diagram, Plate II., the air was blown into the second compartment from the front, and there was only one reduction of pressure on that side of the inlet. The consequence was we were

PLATE VII.

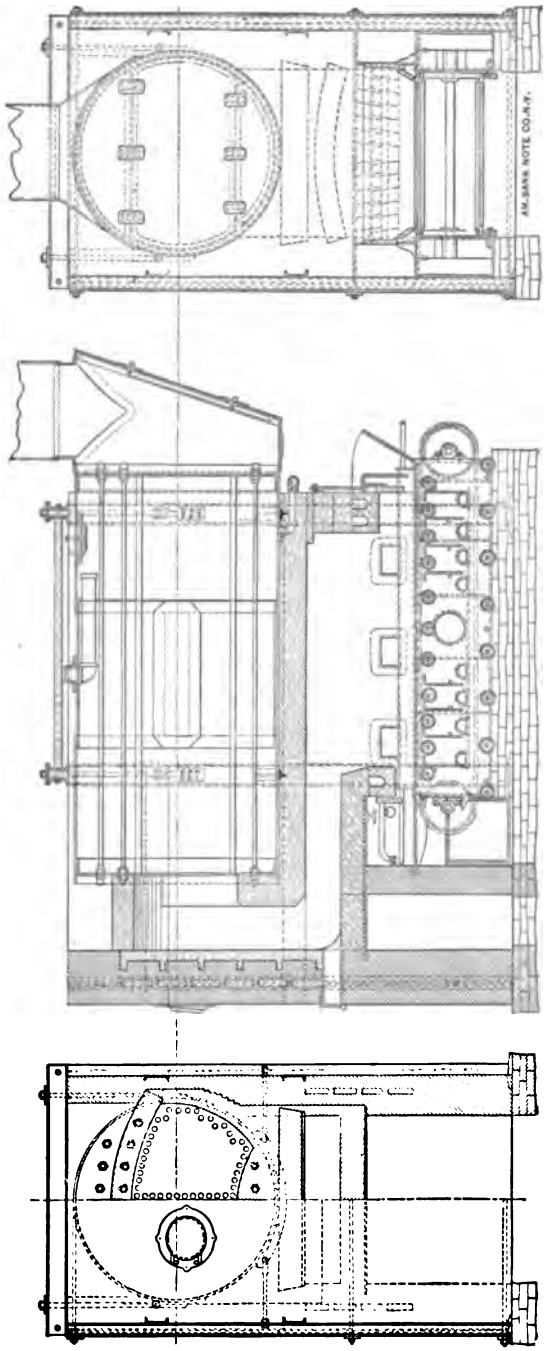

Reducing Mechanism.
H
L
F
M
T—50
T—51
T—10
T—11
S'''
S''
S'
S
K'
K
B
D
AMERICAN BANK NOTE CO. N.Y.

obliged to close the front and put in the water seal, except when using the larger sizes of coal. We found by increasing the number of compartments between the igniting brick and the air inlet, and reducing the pressure gradually towards the front, it was not necessary to close the front or use the water seal. The new construction is shown on Plate VI., where, as will be seen, there are three compartments to the left and three to the right of the main compartment into which the air is blown, and in this way we have very much simplified the construction, using a horizontal bed, but two pairs of sprocket wheels, and no water seal. The fireman has his grate constantly in sight, and can easily see a defective bar and remove it without stopping, as he has from 15 to 20 minutes from the time the bar is first seen until it disappears. As originally constructed, the side frame of the stoker was built into the brick work; but in the new type there is a single casting, entirely open on the outside, so that everything is easily accessible, and the brick work of the furnace starts above it, as is shown in Plate VI. The lower ends of the buckstays are simply fastened to the frame. As from time to time some ash and small coal may fall into the air compartments, provision has to be made to clean them out, or, at least, examine them, although, as the grate is now constructed, there is practically nothing found in the air pan. With the old construction, cast-iron pipes with lids had to be built in the walls and the cleaning had to be done through these pipes, which were from 18 inches to 2 feet long. In the new construction the cleaning doors are directly upon the side of the cast-iron frame. The same may be said of the pipe through which the air is conveyed into the air pan.

As I said before, the heat in the furnace is very intense, and we had a good deal of trouble at first to so construct the arches under which the grate passed in entering and leaving the furnace, and under which the fuel was fed into the furnace, and also the arch over the furnace proper. This has been overcome by getting suitable fire brick, building our arch with care, and thoroughly securing them by good buckstays. We have arches

now, with a span of 10 feet, which are standing perfectly. We try to carry the arch over the fire as far as possible towards the dumping end, so as to maintain an intense heat in the furnace, and not allow the gases to come into contact with the boiler until complete combustion has taken place. We think it better for the furnace and better for the boilers, and in our newest construction, which we are erecting for ourselves, we do not allow any part of the boilers to be subjected to direct radiation of the fire. See Plates V., VII., and VIII. The advantage of this is, first: If you are burning bituminous coal you absolutely do away with the smoke, and in all cases you keep your ashes very hot until near the dumping point. The advantage of this is that the oxygen of the air will take up carbon in the ash when the latter incandescent, long after it would cease to do so if the ashes were cooled off, as they generally are in the bottom of a furnace. We find that in this way we can reduce the percentage of carbon in the ash to almost any point we desire, although, as I said before, it is not economical to push it beyond a certain point. The intense heat of the furnace caused another difficulty, viz., the burning out of what we call the regulating gate. That is to say, the gate or slide which, by closing more or less the orifice over the igniting brick, regulates the thickness of the layer of fuel fed into the furnace, and thereby the depth of the bed upon the grate. We first made this gate of sheet iron and cast iron plates, but they warped and gave trouble. We next made our gate of keys [sectional bars] like those used for the grate, which was in the main satisfactory when the spring of the arch did not expose too much of the iron to radiation. We now make our gate of a row of fire brick 3 inches thick, 18 inches long and 1 foot wide, held together on top by an iron frame. This is perfectly atisfactory. We have also adopted a similar device for closing the dumping end when it is necessary. The construction of this gate is the same as that of the other, although the fire bricks are not so thick. The gate is carried by two iron arms which turn on a shaft and rest upon two cams. By revolving these cams we can make the opening

PLATE VIII.



whatever we need. We have not, however, had very much trouble in preventing the air from entering at the back end, as there is generally a slight plenum in the space over the fire. As the smaller anthracites flow like dry sand when heated, there is no trouble in feeding them over the igniting brick. They run under the regulating gate and over the fire brick just as sand runs through the hour glass. But with bituminous coal it is entirely different. We found that there was no trouble whatever to burn bituminous coal without smoke, except that it would not run down over the igniting brick when exposed to the heat, but would cake more or less. It was necessary, therefore, to break it up occasionally. The hopper for anthracite is shown in Plate V., also on the diagram, Plate II. The bituminous hopper 13 is shown on Plate VI.; through it the bituminous coal, which should be slack, is fed. The bed is formed directly on the cold bars by the coal, which is also cold, by its passing under the iron plate 21, which regulates the thickness of the bed (being raised or lowered by the bolts 76). In order to prevent the radiation from the furnace from heating the cast-iron gate there is a fire-brick gate (14) which closes the opening under the arch. It is so placed that the lower edge (14) is a little higher than the lower edge of 21. Whatever is passed under 21 will pass freely under 14. Each can be regulated independently of the other.

The stokers are all practically of the same length. The distance between the centres of the sprocket wheels is about 12 feet 8 inches, and the part of the grate on which the coal burns is about 9 feet long. The amount of coal burnt per hour varies with the speed of the grate, pressure of the blast, size of the coal, and the depth of the bed of fuel. The amount of coal burnt in cubic feet is the product of the width of the available grate by the depth of the bed and by the speed of the grate. The maximum speed of the grate is limited by the rate at which the fuel will ignite, and the extent to which it is desired to reduce the carbon in the ash or burn out the fuel; for if you run too fast the ignited coal gradually moves from the igniting brick, and com-

bustion gradually ceases, and some of the coal will be carried over and dumped into the ash pit, because there is not time for complete combustion. There must be a certain relation between the pressure of the blast, the depth of the bed of fuel, and the size of the coal. The larger the size of the coal the thicker the bed can be, and the less the pressure of the blast for a given thickness of bed. There is a maximum depth for each size of coal. We generally burn pea coal, with a bed of from 8 to 12 inches; buckwheat, with from 6 to 9 inches; rice, with from 5 to 7 inches; barley, with from 4 to 6 inches. Above these limits we must use too great a pressure of blast, and consequently have too much excess of air in our stack gases, and very often considerable carbon in the ash, due to this excess of air cooling the ash too much. Below the lower limits the combustion is not active, and the bed of ash is so thin towards the dumping end that a great deal of air passes through, and the ash is chilled before being completly burnt. When we wish to moderate the fire—as, for example, when a very small quantity of steam is needed—we can run with a lower pressure blast, thinner bed of fuel, and at a reduced speed of grate, provided we alter by means of the registers the distribution of the air in the different compartments. In this case, however, the coal is generally burnt out before it reaches the end of the grate, and we have what is called a short bed of fire. The width of the furnace is the measure of its capacity instead of the number of square feet of grate surface. That is, a furnace 6 feet wide will burn about 50 per cent. more coal than one 4 feet wide. With fair running a stoker will burn about 225 pounds of pea coal per foot of width per hour, about 175 of buckwheat, 125 to 150 of rice, and 100 pounds of barley. The length has little or no effect upon the amount of coal burnt per hour. If the grate is too short we do not get as good ash, nor can we control our stack gases as well. We have not determined absolutely the best length, but it seems to be about 9 feet.

I will conclude by giving a *résumé* of what we think, or at least hope, can be accomplished with this machine. The

coal can be supplied automatically, and is so in many of our plants, the fireman having absolutely nothing to do with handling the coal, except to see that the machinery that brings the coal to the proper point in the boiler house is kept in motion. There is no cleaning of fires, no slice bars are used, and it makes no difference whether coal clinkers or does not, for the clinker is dumped off with the other ashes and gives no trouble. It is not necessary to open the fire doors for any purpose when the furnace is in operation. The boiler is not strained, as it remains always at the same temperature, unless we do not need the steam, in which case it is cooled off gradually. We can and do use intelligent men as firemen, the work is comparatively pleasant, requiring no severe exertion, but thought and attention. The fireman has simply to watch the gauges, engine, fan, &c., and see that everything is running properly. In addition, no matter whether you have a thousand horse power or a hundred horse power, you need practically the same number of men.

We can blow with dry air. It is not necessary to use steam to partially prevent the formation of clinker, and consequently we avoid the loss due to heating the steam in the fire, the waste of it in producing the blast, and the effects of its decomposition. While the furnace is running regularly it produces at all times the same results; that is to say, you are always evaporating exactly the same number of pounds of water per minute, and can therefore furnish a steady supply of steam. No time is lost in cleaning fires, nor is cold air introduced when shoveling in coal, &c. If it is desired to reduce the production of steam, it is only necessary to slow down the engine so as to reduce the blast, the speed of the grate, and, if it is desired, the thickness of the bed of fuel can be changed. By means of the registers between the different air compartments we are able to regulate the supply of air in all parts of the bed of fuel so as to get the best results, and to control to a large extent the composition of our stack gases; without difficulty we can obtain over 16 per cent. of carbonic acid and less than 3 per cent. of free oxygen without carbonic oxide, a result hardly possible

with hand firing, at least we have not been able to find such percentages in any of the published reports of tests. The same thing applies to the ash. We can, by regulating the thickness of the bed, the speed of the grate, and the distribution of the air, reduce the ash as low as is probably economical. We have obtained ash very low in carbon, but we think it was at the expense of capacity, and probably also of heat in the stack gases—too much air being introduced. We can certainly burn the finer coals with a less excess of air than we hoped for or than is generally done. We have shown that the amount of water evaporated per pound of coal does not depend practically upon the size, but only upon the amount of heat units or combustible in the coal. We have found that we could use coal very high in ash without diminishing very materially the number of pounds of water evaporated per pound of combustible; but we have also found that the purer the coal and the larger the size, the greater is the capacity of the boiler. That is to say, that we can evaporate more water with a given boiler, the purer the coal and the larger the size, although the quantity of water evaporated per pound of combustible is practically the same in all cases, so long as there is no great excess of dust in the fuel, which in that case stops up the air passages between the pieces of coal and thereby prevents a regular blast and even burning of the fuel. We have also found that we could burn bituminous coal without difficulty, and by properly regulating the air avoid absolutely the production of smoke. We think that by providing sufficient grate surface we can evaporate as much water, or nearly as much, with a ton of No. 3 buckwheat or rice coal as we can with pea coal, provided they are equally free from impurities, the only additional expense in the case of the small coal being the interest and depreciation on the additional plant necessary to produce a given amount of steam.

In conclusion, I give in Table XIX. a record of a test made at the Eagle Oil Works, Claremont, N. J., with a 4-foot stoker under a return tubular boiler.

TABLE XIX.

Report of Test of a Return Tubular Boiler Equipped with a 4-foot Coxe Stoker Burning Anthracite Buckwheat Coal.

1	Duration of test	15 hours
2	Pounds of water evaporated per pound of dry coal—actual conditions	8.15
3	Pounds of water evaporated per pound of dry coal, from and at 212° F.	9.59
4	Pounds of water evaporated per pound of combustible, from and at 212° F.	12.38
5	Pounds of water evaporated from and at 212° F. per hour	....
6	" coal per square foot of grate per hour	....
7	" " hour	586.3
8	Average temperature of escaping gases	460
9	Horse power actually developed	163
10	Square feet of heating surface per horse power	10.74
11	Percentage above rated capacity	48.80
12	Moisture in steam	....
13	" coal as fired	6.00%
14	Per cent. of ash in ash pit	22.70
15	Carbon in ash	11.92%
16	Pressure, average, of steam	83.30
17	" " blast in inches of water in entrance chamber,	¾
18	Temperature of feed water, average	75°
19	" outside air, average	....

Analysis of coal:	Moisture	3.11%
	Volatile combustible matter	3.39%
	Ash	17.15%
	Carbon	76.35%
Slate test:	Pure coal, specific gravity below	....
	Slate and bone, specific gravity above	....
Sizing test:	Pea, through ⅞-inch and over $\frac{9}{16}$-inch mesh	12.97%
	Buckwheat " $\frac{9}{16}$ " ⅜ "	51.93%
	Rice, " ⅜ " $\frac{3}{16}$ "	27.32%
	Barley, " $\frac{3}{16}$ " $\frac{3}{32}$ "	4.65%
	Culm, " $\frac{3}{32}$-inch mesh	3.10%

We made a large number of tests with the same plant with various sizes of coal, and the results of some of them are given

here to show how little difference there was between the amount of water evaporated per pound of combustible (and even per pound of fuel) for the different sizes, and although they did not all come from the same mine.

	Pounds of Water Per Pound of Coal from and at 212° F.	Pounds of Water Per Pound of Combustible from and at 212° F.
Buckwheat	8.77	11.07
Rice (No. 2 buckwheat)	9.05	11.18
Culm (pea, buckwheat, rice, barley, and dust)	8.74	11.19
Barley (No. 3 buckwheat)	8.39	10.89

APPENDIX.

*Thermal Capacities (Specific Heat) of Gases and Vapors at Constant Pressure.

GAS OR VAPOR.	EQUAL.	
	Volumes.	Weights.
Air	.2375	.2375
Oxygen	.2405	.2175
Nitrogen	.2368	.2438
Hydrogen	.2359	3.409
Methane (Marsh gas)	.3277	.5929
Carbonic oxide	.2370	.2450
Carbonic anhydride	.3307	.2163
Steam	.2989	.4805
Suphurous anhydride	.3410	.1540

*Taken from Miller's "Chemical Physics," page 308; Prof. J. D. Everett's "Units and Physical Constants;" Dr. A. Naumann's "Technisch-Thermochemische Berechnungen."

HEATS OF COMBUSTION.

One pound C to CO_2 gives 8140* Calories or 14650 B. T. U.
" " C to CO " 2474 " or 4450 "
" " C from CO to CO_2 gives 5666† Calories or 10200 B. T. U.
" " CH_4 to $CO_2 + H_2O$ " 13305 " " 23950 " "

*Berthellot, Coll. Guardian, Vol. 64, page 237.
†Dr. Alex. Naumann's "Thermochemische Berechnung zur Heizung," page 4.

*Composition of Air (Dry).**

	BY WEIGHT.	BY VOLUME.
Nitrogen	76.815	79.04
Oxygen	23.185	20.96
N O	3.313	3.7709

*J. P. Cooke's "Principles of Chemical Philosophy."

**Absolute Densities of Gases in Grammes per Cu. Centim. at 0°C., and a Pressure of 10^6 Dynes per Sq. Centim.*

	One Cu. Centimeter in Grammes.		One Gramme in Cu. Centimeters.	
	Weight.	Log.	Volume.	Log.
Air (dry)	.0012759	1058166	783.8	8942053
CO_2	.0019509	2902350	512.6	7097786
CO	.0012179	0856166	821.1	9143961
N	.0012393	0931764	806.9	9068197
O	.0014107	1494347	708.9	8505850
H	.00008837	9463049	11316.0	0536929
CH_4	.0007173	. . . . .	1394 1	. . . . .
SO_3	.0026990	4312029	370.5	5687882

* Prof. J. D. Everett's "Units and Physical Constants."

The SECRETARY. In order to rest the audience, I suggest that we have a recess of five minutes before taking up the next paper.

The PRESIDENT. The Association will take a recess for five minutes.

A five-minute recess was then taken, and the President again called the meeting to order.

The PRESIDENT. The next paper is No. 10, "Operating by Electricity from a Distance," by Mr. JOHN ECCLES of Taftville, Conn.

OPERATED BY ELECTRICITY FROM A DISTANCE.

MR. JOHN ECCLES, TAFTVILLE, CONN.

There being no plant in Baltic to use the great water privilege, our treasurer, Mr. E. P. TAFT, decided to carry a part of this power going to waste, by electricity to Taftville, a distance of four and one-half miles, to run our weaving mill of one thousand seven hundred (1,700) looms and one thousand two hundred (1,200) lights, which were run by two Harris Corliss Engines, size of cylinders 20 inches by 48 inches, and 22 inches by 48 inches, using about 375 horse power for running the looms, 125 horse power additional when the lights were on, weaving various styles of fancies, etc., consuming on an average forty tons of coal per week at a cost of eight thousand dollars ($8,000) per year.

This, as you will readily see, was quite an expense, while water was running away at Baltic. This idea suggested itself—to run by electricity from a distance of four and one-half miles. The cost of the plant once put in was good for all time, whereas the coal was constantly to be consumed. It is not possible for me to give the exact figures as to cost of installing our electric plant and maintaining it, but I know it has been much higher than it otherwise would if the power were all in use; we are only using one-fourth of the whole power. When Baltic starts manufacturing in the mill erected, the same hands will do the work. This will greatly reduce the cost in labor. The water power is utilized by two double 42-inch horizontal wheels, and one double 27-inch, the former developing 800 horse power at 159 revolutions, and the latter 300 horse power at 244 revolutions. These were built by P. C. HOLMES, Gardiner, Me., making 1,900 horse power in all. This wheel room being a model,

perfect in all its appointments, must be seen to be appreciated. These wheels are in line and parallel with the main line that runs the electric generators, and are arranged by clutches and quills so as to run any one separate or in unit. The plant consists of two three-phase 350 horse power generators of such design that a temporary overload of 50 per cent. may be carried for a short time, and, as occasional overloads are unavoidable, this is a most desirable feature. The generators run at 600 revolutions and drive the two 350 horse power motors at Taftville, at precisely the same speed, there being less than one-tenth of a revolution difference in an entire day's run, it being as though there was a continuous shaft extending from the water wheels at Baltic to the mill at Taftville. The motors connect with the generators at Baltic by two sets of wires so arranged that by means of the new switches just being completed, either generator can drive one or both motors, and, in case of accident to any set of wires, the entire machine can be immediately transferred to the running wires, the only difference being a slightly increased loss of energy in transmission. The loss in the wires at full load is 7 per cent. and in motors and generators 5 to 7 per cent., giving a total loss of about 18 or 20 per cent. from main shaft at Baltic to main shaft at Taftville. On end of the armature the large 34-inch belt revolves; when this gets in motion he clutch on main shaft is thrown in, setting all the other shafts in motion and driving the machinery. There was great speculation as to its giving perfect speed; this was all allayed when we had run a short time. The speed is perfect as any regulator on water-wheel can give. We are having a water-wheel governor built that will regulate the most variable loads and are intending to run the Norwich Street Railway in connection with the mill. A few weeks ago we put in a new governor built by the Lombard Water Wheel Governor Co., of Boston, Mass. That gives most perfect speed, running the Norwich Street Railroad in connection with our looms. We counted the speed most continuously for a whole afternoon when the street

railway runs the largest number of cars and the loads are the most variable. Did not get at any time over 2 per cent. variation.

The main object of these few remarks is to demonstrate the fact that water privileges, which have been considered worthless because of the unsuitableness for building mills or any manufacturing industries, can be made of great value. The handling of freights is a great factor in these days of great competition. A mill can be located for all the requisites, carrying the power from where it is generated to the most desirable point needed. This, it seems to me, is bound to prove itself of advantage in the cost of running plants where there are large water privileges going to waste on account of the unfitness of the location.

We also use an electric locomotive which is a model of electrical and mechanical ingenuity, and is not only a large and highly efficient machine, but is together, both in its air brakes and speed controller, the best in design, and up to date, one of the most powerful electric locomotives ever constructed. We use it to draw all our freight cars from Taftville one mile to mills. This we formerly did by horses, and it was a very slow operation. We had three men and five horses, at an expense of $8.50 per day. A good day's work was to draw eleven cars costing about 77 cents a car, and we used the most powerful horses that could be found. The wear and tear of harnesses, etc., was very great, particularly in the winter months, shoeing alone costing treble what it ordinarily does on regular roads, breaking of chains, all necessitating constant repairs. We had men who were thoroughly trained in handling these horses, who had done it for years. With the electric locomotive we can make three trips in one hour, hauling three to four cars at each trip, or thirty-five daily, cost $2.75 a day or 8 cents a car against 77 cents. There is a great saving of time that was lost by men waiting between moving the full and empties. We used to lose ten to fifteen minutes with ten or twelve men in making these changes; this was very annoying. I have no hesitation in saying that we could pull—providing that we had sufficient current

to supply the motors — a full train of forty loaded cars with forty bales of cotton in each. The weight of our locomotive is 62,000 pounds. It is equipped with four 125 horse power motors and has a maximum speed of 30 miles per hour. with four loaded cars on our track, up grade, with two curves, the speed is 8 miles per hour. The maximum horse power is 800; the designed horse power is 500. Traction and draw bar pull is more than new steam locomotive of same weight. Curves are six times heavier than allowed on steam railway. Have one grade that rises 5 per cent.

Average horse power used during a day's run,	50
" " " " " loads,	75
" " " " " light running,	25

Current running light 30 to 50 amperes.
" " 1 car 50 to 70 amperes.
" " 2 cars 50 to 80 "
" " 3 " 60 to 90 "
" " 4 " 60 to 110 "

The above is the necessary current. If speed is increased the current will rapidly rise.

Locomotive will run fifteen cars to the depot on same current used to bring two to four up. Maximum current is required at depot as track is double curved and very sharp at this point and requires 150 to 200 per cent. of power needed elsewhere. The working of it is perfect in every way as far as we have seen up to date. Will be pleased to show any member of the Association these electric machines.

MORNING SESSION, APRIL 25, 1895.

The President called the meeting to order at 10 A. M.

The PRESIDENT. The Secretary will give a few notices this morning.

The SECRETARY. I am requested by the Local Committee to give another notice relative to the dinner this afternoon. Street cars will leave from the front of this building at 1 o'clock, and take the party to the Pomham Club. I understand that there has no one been invited to this dinner except the members of the Association, and the members elected. Tickets will be necessary for the dinner, and can be obtained from the Secretary of the Local Committee, Mr. SULLY, in the ante-room.

The evening session will be held at eight o'clock. Notifications of election have been prepared for those members whose names were on the large ballots, and they can obtain their notices to-day.

The notifications will not be ready this evening for those who will be elected on the ballot to be presented sometime to-day.

The PRESIDENT. The first paper this morning is No. 9, "Electrical Driving of Textile Establishments," by Mr. SIDNEY B. PAINE, Boston, Mass.

ELECTRICAL DRIVING OF TEXTILE ESTABLISHMENTS.

MR. SIDNEY B. PAINE, BOSTON, MASS.

The modern cotton mill affords a most striking example of what may be achieved by intelligent and persistent study. To the uninitiated it may seem a simple matter to feed the cotton to the opener, to follow it through the several processes, and finally to take the cloth off the loom. The mill seems to run itself, so perfect is the adjustment. An ordinary observer cannot appreciate the long development through which the machinery before him has passed before arriving at its present perfection. He does not see the scrap heap into which have been thrown machines which but yesterday seemed to fulfil all requirements. This is not extravagance. Competition, shortened hours of labor and multiplication of establishments compel the successful manufacturer to disregard such expenditures, provided the operating expenses may be reduced or the volume of the product be increased, while yet the quality is maintained.

"Let well enough alone" is not the motto under which the members of this Association have advanced the science of cotton manufacturing to the position which it now occupies. You are content with present methods and machinery only with the expectation that to-morrow, profiting by the experience of to-day, you will reach still better results. It is not strange, therefore, that in an age abounding in startling and successful applications of electricity, you should, without distrust or prejudice, look for the profitable utilization of this agency in the driving of your mills.

In order that those of your number, who have not had an opportunity to fully investigate the matter, may have a better understanding of what the electric system is and what it can do,

the writer has been requested to state as clearly and concisely as possible the principles which underlie it, and also the results which will ensue from a correct application of these principles. In complying with this request, technical terms will be avoided, as far as possible, even at the risk of appearing elementary,

In the consideration of this subject, it must be borne in mind that the electric generator, so-called, does not generate, or rather does not originate, the energy which is to be utilized in the driving of the establishment. Power must be applied to it from without. It receives this power in the form of mechanical energy, and transforms it into electrical energy. This is transferred in its new form by means of conducting wires to the motor, where it is retransformed and appears again as rotary motion, to be then applied to driving of the machinery, either directly or through small shafts and belts.

The electric system, therefore, affords but another means of transmitting power from the prime mover to the point of its ultimate application. Its function is to replace, to a greater or less degree, mechanical methods of transmission, such as shafting, belting, ropes, gearing, etc.

With this explanation clearly in mind, let us compare this system with the mechanical systems heretofore in vogue. We shall find however, that its adoption will lead to results which we had not anticipated when we commenced our investigation, and that it very materially assists in the removal of many difficulties which have hitherto been encountered.

MECHANICALLY DRIVEN PLANTS ESTABLISHED ON A COMPROMISE BASIS.

In the erection of a manufacturing plant, in which mechanical methods only are employed, the engineer is confronted by many distinct and separate problems.

If steam is to be used as the motive power, he must decide upon the best location for the receipt of the fuel, proper regard being given to the facilities for the transportation of the coal

from the cars or wharf. He must provide also for an adequate supply of water, of proper quality, for steam and condensing purposes. He must have in view the economical disposition of the ashes. While the boilers, chimney and engine must be placed upon solid foundations, it is eqnally essential that the engine house be placed as near as possible to the manufacturing buildings, and be so located that the power may be delivered at the proper point and at right angles to the main shafting.

If water wheels are to be used, the engineer must determine the best location for the dam, giving proper consideration to the questions of flowage, foundations, anchorage and head of water. He must enter the canal at the most advantageous point and make it as short and as direct as the topography of the country will permit. He must secure a suitable mill site adjacent to the canal, and must erect the buildings upon solid foundations. He must make adequate provision for the receipt of supplies and the shipment of the manufactured product.

The most economical plan of transmission and distribution of the power must be determined. Theoretically it should be applied as nearly as possible at the centre of the machinery to be driven. All angles and turns in the line of transmission should be avoided; otherwise wasteful and cumbersome appliances must be adopted. In locating the machinery, the direction of rotation must be borne in mind or cross belts wlll be required. He must provide for a possible enlargement of the plant.

The engineer is unable to study each one of these questions by itself and adopt that plan in each particular instance which would give the best results, independent of the others. He must constantly bear in mind the relations of one to the other. He must make a concession here, and must sacrifice there, in order that the plant in its *entirety* may be as nearly perfect as possible. The cases are exceedingly rare in which equally good results can be obtained *collectively* as would ensue if he were at liberty to consider each branch of the subject alone in all its details.

COMPARATIVE SIMPLICITY OF THE ELECTRIC SYSTEM.

The engineer, on the other hand, is not thus hampered when using the electric system. The generating station is located where the power may be produced most easily and economically. Independent consideration is also given to both transmission and distribution, and only such conditions are adopted as will give the highest degree of efficiency, everything considered. Within reasonable limits, the manufacturing buildings may be located, without regard to their relative position to the power house or to their distance from the source of power. The mill site may be selected with a view to obtaining cheap and solid foundations, and at such point as will secure the best conditions for manufacturing. It is not necessary, as is oftentimes the case with the mechanical system, to subordinate everything else to the power (the cost of which is one of the smallest items entering into the value of the finished product), or in other words, to sacrifice nearly every other consideration in favor of the site for the power house. You can recall many instances where the determining factor was the facility for obtainfng suitable water for the boilers and condensers. The writer recently had occasion to visit a factory situated beside a magnificent water power; the mill site was at the foot of a very steep hill, where the light was poor and the access to the mill was equally bad. The electric system frees the manufacturer from any such restrictions, and permits him to locate each building with regard only to the processes carried on *within* that structure. In the case just alluded to, the mill would have been located on the top of the hill, where the light was all that could be desired, and where it would have been on a level with, and adjacent to the railroad.

The electric motor is independent of the prime mover, both as to location and direction of rotation, the latter being readily changed if desired by the transposition at the motor of the connection of either two of the three conducting wires.

There is no loss by reason of angles in the line of the conductors. They may be taken around corners, or run in any direc-

tion. Their position may be changed at will, while transmitting the maximum power, without interference with the service. There is nothing to explode or drip. Inasmuch as there is no mechanical strain upon them, they will not break down or give way, unless some outside force is brought to bear upon them; neither are they affected by atmospheric changes, as is the case with belting or ropes. Since there is no movement to the wire, it is possible to transmit the power into rooms, into which it would be impracticable or exceedingly awkward to transmit it by mechanical means.

The speed of the shafting is limited only by considerations of safety, and by the size of pulleys available on the machines to be driven, and is determined without reference to that of the prime mover.

SUBDIVISION.

The several rooms in the mill may be divided into independent sections, each driven by its own motor, thus permitting the operation of either section, without driving the shafting and belting in other portions of the mili. This subdivision also insures against stopping the entire plant in case of accident within the mill buildings. Recently the writer was in an electrically driven weave shop, when it became necessary to put on a small belt. Only that portion of the room driven by one motor was shut down while this was being done.

The generating plant, where its size will permit, may be divided into several units, each consisting of a prime mover and a generator. These will deliver their currents into a common conducting wire. In the event of an accident to either one of these units, if spare capacity has not been provided, the load may be reduced to the capacity of the remaining units, by the switching off of such motors or lamps as will least interfere with the general service. It would not be necessary to shut down the entire establishment until the repairs were completed. The

time thus lost may be made up by running overtime only the machinery temporarily stopped.

While provision is thus made to reduce to a minimum the loss of time due to an accident, it should be understood that this is done because of greater liability to such trouble due to the adoption of the electric system. As a matter of fact, a properly constructed plant will be almost entirely exempt from interruption on this account. Insulated with the utmost care, exceedingly simple in their construction, the generators and motors offer far less points of weakness than are present in the mechanical system. This subdivision is recommended, rather, because of the possibility of trouble with such shafting or belting as is retained (as in the weave shop cited above), and because of the great flexibility obtained, in that any section, which may be behind in its production, may be operated overtime.

The power required to operate each section may be readily ascertained, and, if desired. a continuous record of same may be kept. When any change is made in the product, the variation in the amount of power used may be determined. Each department may thus be charged with its true proportion of the total cost of the power delivered by the prime mover. A check is also provided against undue consumption of power by reason of poorly lined shafting or other causes. With the mechanical system the cost of power consumed in the main drive can be distributed only approximately, and the amount used in each department can be known only after an expensive power scale test which will be of value only as an indication of the amount of power used *at that time*.

The limit to which the subdivision may be carried will depend largely upon the relative economy of the motors employed and upon the uniformity of the load. It is evident that if the load is very variable, a smaller and consequently less efficient motor may be used, as the saving in the power which would otherwise be used by the idle shafting will compensate to a greater or less degree for the lower efficiency of the smaller motor.

By reason of the above subdivision, the diameter of the shafting and the width of belting on any section are determined solely by the amount of power necessary to drive that section, and are independent of the total power required to operate the mill.

In the Columbia Mills, of Columbia, S. C., which will require some 1,400 horse power, the largest shaft measures three inches in diameter, and but two belts as wide as nine inches are used. In the spinning room there is no line shafting. The motors are suspended from the ceiling over the centre of the room and are belted to the countershafts from which the frames are driven. The room measures 380 feet by 102 feet, yet the longest shaft is ten feet in length, this being the counter which runs from one beam to the next, over the ends of the frames. The ceiling is entirely clear of shafting or belting, from this point, for the length of two frames, where another motor is suspended with its set of countershafts. On each end of the motor shaft, two pulleys are placed and from these two belts lead in opposite directions to the counters. As these belts are horizontal, all side strains upon the motor boxes are avoided, thus reducing the friction to practically that of the counters alone. In the picker room of this mill the motor is coupled directly to the shafting which drive down on to the machine as shown in Figure 1.

Where the conditions are such that the motor cannot be belted to the counters, as above described, it should be preferably so located that it can be belted to the centre of the shaft driving the section. Not only is the diameter of this shaft thus still further reduced, but the section is readily subdivided, for, by removal of the coupling bolts, the shaft on either side of the driven pulley may be stopped when desired.

In the No. 4 mill of the Pelzer Manufacturing Company of Pelzer, S. C., now being equipped with the electric drive, and which will require about 2,000 horse power, the largest shaft measures 2 15-16 inches in diameter, and the largest belt is 8 inches in width. In this mill the saving in first cost of the

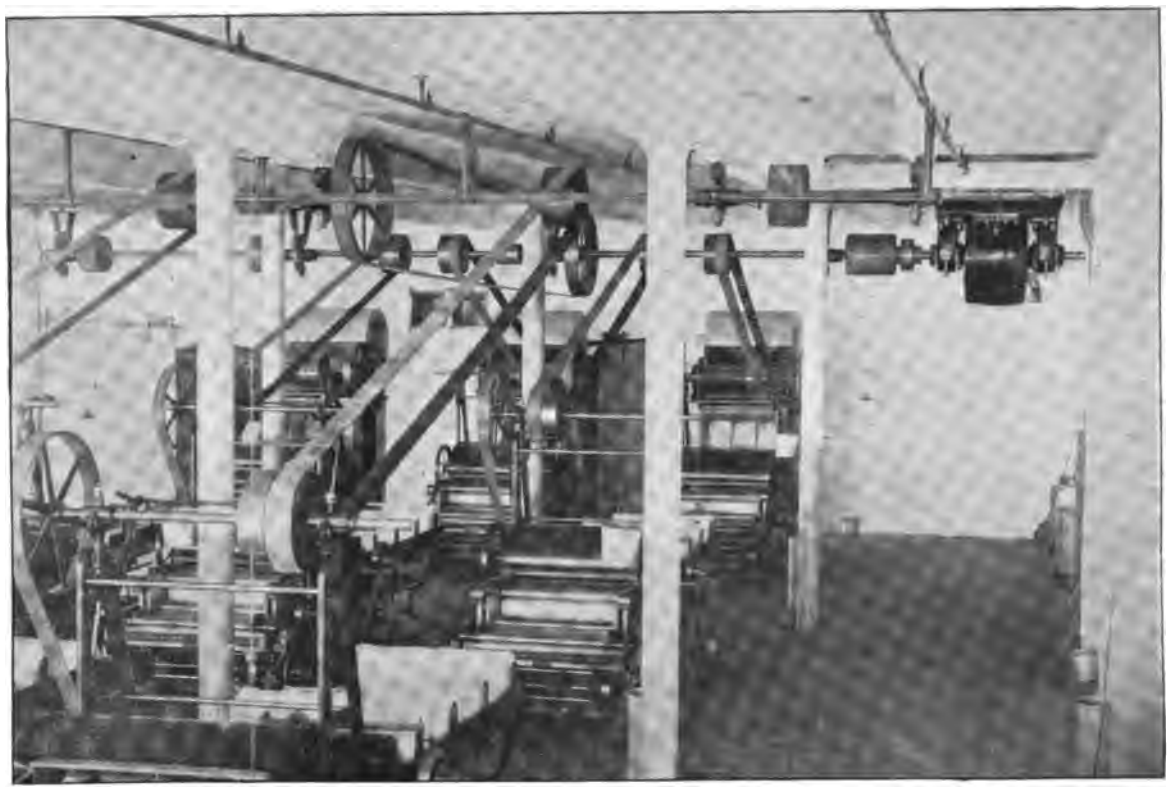


FIG. 1.—COLUMBIA MILLS PICKER ROOM.

shafting and belting, as compared with an identical mill driven by the mechanical system, will amount to nearly $10,000. The saving in belting is principally in the main drive. By reason of the subdivision into independently driven sections, the *number* of belts may be larger than on some mechanical systems. The width of the belting is, however, very materially reduced.

The belt tower, and all its accompaniments are omitted. In the Pelzer Mill, this omission resulted in a saving of over $3,000.

Not the least of the advantages, resulting from the reduction in the amount and size of shafting and belting, is the removal, to a corresponding degree, of the source of the frictional electricity found upon the belts and the machines.

The cost of replacing and repairing the belts and of lining up the shafting is also greatly diminished.

CONCENTRATION.

The electric drive invites concentration of the manufacturing buildings at one central point (chosen without reference to the position of the power house) where they may be under the intelligent and interested supervision of the management. Not only are better results thus obtained, but there is a considerable reduction effected in the amount of the higher grades of labor required.

Water powers, more or less widely separated, may thus be brought together for utilization. If steam power is to be used, it is also manifestly more economical to concentrate the buildings, and to use one large steam plant, with interchangeable units, than to use several isolated plants.

To paraphrase a familiar expression, the power is moved to the mill, and not the mill to the power. Examples of this feature will be found in the description of installations mentioned later.

EFFICIENCY.

On a mechanically driven plant it is very difficult to determine

the efficiency *under load.* Ordinarily, the total power required to drive the shafting and belting (the machine belts being on the loose pulleys) is measured, and from this is deducted the loss in the engine or wheel when disconnected from the jack shaft. This method simply shows the power required to keep at speed the hundred of tons of shafting and pulleys, and to overcome the friction of shafting revolving comparatively freely in the bearings. It entirely ignores the additional friction and loss due to the increased load when the main belts are shifted to the tight pulleys. Weight or pressure is one of the factors which determine the amonnt of friction. Increased load must cause more pressure on the boxes and therefore increase the loss in transmission. Again the ratio which the power delivered by the prime mover bears to the amount realized at the machines, is constantly changing. It is not the same to-day that it was yesterday, depending as it does not only on the load, but also on the condition of the bearings and on the alignment of the shafting. This latter item especially has a much larger importance than is usually attributed to it. Many an overloaded engine has been relieved by a correction of this evil. No foresight can prevent it. It is the inevitable result of the settling of the building, and of the constant vibration and strain. It requires continual watchfulness and expenditure, or it will seriously increase the losses of transmission, and also affect the output by overloading the belts, thus causing them to slip with consequent reduction in speed on all the machines driven thereby.

On an electrically driven plant, however, the actual loss between the generator shaft and the motor shafts remains practically constant under the same conditions of load, and its value under varying load is readily ascertained. The efficencies of generators and motors under varying loads are determined before the machines leave the shops. The loss in the conducting wire may be easilv measured, and thus the efficiency of the plant as a whole may be computed. This latter will be found to be much more uniform and nearer the maximum at all times, than on the mechanically driven plant.

The efficiency of a direct connected generator of large size is so high, that the combined mechanical and electrical loses in the generator and in the engine or water wheel to which it is coupled, are very little, if any, more than they would be in the same engine or water wheel and in the first belt on a mechanically driven plant. The loss on the inside wiring of the mill and in the motor is no more than the loss on the shafting and belting even under the best conditions as ordinarily determined. The efficiency of the plant as a whole is therefore fully as high as where the power is transmitted mechanically, if the power house be located near the mill buildings. On long distance transmission, however, its superiority is immediately and strikingly apparent.

The efficiency of an engine or water wheel drops very rapididly as the load is reduced. A generator or motor also losses efficiency under these conditions, but to a much smaller degree. The loss on the conducting wire, however, is in direct proportion to the load. If, for example, the loss in the wire is fixed at 10 per cent. at full load, the loss at half load, if the voltage at the motors be maintained constant, is only 5 per cent., thus compensating in large measure for the reduced efficiency of the generator and motors. The lower the percentage of loss in the wire, the less the value of this compensation will be, but it exists to a greater or less degree in all installations. The efficiency of the system as a whole, will therefore remain at a nearly constant percentage. Thus, on a plant requiring 500 horse power to drive the generator, using one generator driven by a belt, and several induction motors of from 50 to 100 horse power capacity each, the mill buildings being say 1,000 feet from the power house, with a loss of 5 per cent. in the wire under full load, the efficiency of transmission, under maximum conditions of load, will be 80 1-2 per cent; under half load, the same plant will show an efficiency of 78 1-2 per cent. With the generator coupled directly to the engine or water wheels, the balance of the above conditions remaining the same, the above efficiencies

at full and half load would be 81.35 per cent. and 80.18 per cent. respectively.

Since the amount of copper in any transmission line varies directly as the square of the length of the line, the distance to which it would be possibie to economically transmit the current would be very limited, if it were not that the size of the wire also varies *inversely* as the square of the voltage. If, therefore, in the above example we suppose the generator to be located say five miles from the motors, a higher voltage would be required, and transformers would be used to reduce this voltage at the mill to an amount suitable for the motors. Under these conditions, the efficiencies of the plant, with belted generator, would be 78.15 per cent. and 73.03 per cent. at full load and half load, respectively; with direct connected generator the efficiencies would be 78.91 per cent. and 74.56 per cent. respectively. With a larger generator, the efficiency under any conditions of load would manifestly be higher than on the machines used by way of illustration. It is therefore evident that the call for power, at the point of generation, under ordinary conditions, is approximately in *direct proportion* to the amount used by the machines thus driven. In any given plant where the load, voltage and distance of transmission are known, neglecting small variations due to temperature, the loss in the conducting wires depends upon their size. This is carefully computed and is largely dependent upon the *value* of the power lost therein. If the latter is expensive, a larger wire is used, and less power will be lost; if it is cheap, a smaller wire is employed with a corresponding increase in the amount of power consumed. The most economical point is determined by the relation which interest, and cost of maintenance of the conducting wires, bears to the value of the power lost therein. A lower efficiency of the plant when operating at full capacity is, consequently, oftentimes more *economical*, everything considered, than a higher efficiency, especially in cases where the load is variable and is at its maximum for only a short period of time. The application of the

electric drive to machine shops or other places where there is liable to be much idle machinery, is especially advantageous, as the most economical degree of efficiency may be adopted after a careful study of all the conditions.

ENLARGEMENT OF AN EXISTING PLANT.

In the enlargement of a mechanically driven plant, it is oftentimes necessary to reconstruct the entire driving arrangement, or to erect a new drive from the prime mover. It is generally impracticable to extend the existing system, as the size of the main shafting and belting will not permit it, and also because much power would be wasted by reason of the indirectness of the drive. The writer has been informed by the agent of one of the best known mills in New England, that on a portion of his factory, erected subsequently to the main buildings, but 64 per cent. of the power delivered to the jackshaft appears at the countershaft.

The electric system would afford a simple and profitable solution of such a problem. The conducting wires would be led by the shortest practicable route from the generator to the point where the additional power was required. There would be no interference with the existing systems and no interruption in the operation of the machinery already installed.

SAFETY.

The question of danger from fire, and also to the operative, has often been urged against the electric system.

In so far as the first is concerned, the underwriters will assure you that a *properly* constructed electric plant is as safe as the best constructed mechanical drive.

By the use of motors suspended from the ceilings of the rooms, requiring only the attention usually given to the self-oiling bearings of the most approved type, there is no opportunity for an operative to receive a shock, except by design. The maximum voltage used inside of the mill is, however, much

below that fatal to human life. An accident might occur from the shaft oiler falling upon the moving machinery below, but this danger would exist, irrespective of the voltage, or in fact if the electric drive were not present. At the generator the voltage used is sometimes dangerous, but every precaution is taken to so insulate every portion of the machinery, that this danger is reduced to a minimum. It should be added, however, that when this high voltage is used, transformers are located at the point where the wires enter the mill, to reduce the voltage to an amount suitable for the induction motors, so that the shaft oiler is not liable to injury on this account in his work around the motors. The only one thus exposed is the attendant in the power house, who is of a much higher degree of intelligence than the average operative, and who has been thoroughly trained in the care and handling of the machine. For that matter, the danger is no greater than in an ordinary engine room, and one would have as much excuse for attempting to take hold of the rapidly revolving spider of the fly wheel of the engine, as for coming in contact with the "live" portion of the generator. In either case, the accident would be due only to the grossest carelessness.

COMPARISON OF SYSTEMS.

Having thus compared the electric drive with other methods, let us examine briefly the two systems of electric transmission now in operation.

The use of the alternating current antedates the employment of the continuous current by many years. The revival of the former system for lighting dates back about ten years, but it was not until considerably later that successful attempts were made to utilize it for the driving of motors. Until that time the electric motor was open to many criticisms, and its use in textile establishments was surrounded by many limitations. The generator was of the continuous current type, which required the use of a commutator, and care was required to avoid spark-

ing at the brushes. This sparking caused depreciation and heating and endangered the operation of the entire plant. The alternating current generator does away entirely with this point of weakness; instead of an expensive commutator, we have three collecting rings, and only neglect can cause sparking at the brushes. An alternating current generator is shown in Figure 2.

The distance of transmission was formerly limited, by reason of the comparatively low voltage required at the motors, and for this reason the first cost was, in most cases, prohibitive, where the distance between the generator and motors exceeded one and a half miles; in addition, incandescent or arc lamps could not be properly operated from the power wires at even that distance. To-day it is perfectly feasible, by the alternating system, to economically transmit the current twenty-five miles, and use the same system for lights as well as power.

The continuous current motor, like its generator, must be equipped with a commutator, and here was one of the most serious drawbacks to the use of the electric drive in many of the manufacturing departments of a cotton mill. Inattention, which permitted dust or other foreign matter to accumulate under the brushes, caused sparking, with attendant danger of fire. The regulation was poor, the speed variation on changes from full load to no load being in some cases as high as 6 per cent., altogether too wide a range for cotton mill work. By reason of its construction, the motor would burn out if too heavily overloaded. With the alternating current induction motor, all this is changed. It has no brushes or commutator and there can therefore be no sparking. It can be so constructed as to show a speed regulation within 2 per cent. on changes from full load to no load. If too heavily overloaded it will stop and wait, without injury to itself, until the overload is removed. No outside starting box is required. The motor may be suspended in an inverted position from the ceiling of the room, and the starting resistance be firmly fastened to the spider of the armature,

and controlled from the floor by a removable lever. An inverted motor of this type is shown in Figure 3.

In addition to the induction motor described above, there is also another type of alternating current machine known as the synchronous motor. It is to all outward appearances similar to the generator. This is a most useful machine where strong starting effort is not required and where the use of brushes would not be an objection. It is especially valuable where exact speed regulation is a necessity. Although it may be separated many miles from the generator it will run at a uniform speed, irrespective of changes of load, provided the generator speed be maintained constant. As it is designed for the same voltage as the generators, it is not necessary, in a majority of cases, to use transformers. For this reason, and because of its construction, the synchronous motor may be installed in many instances at a cheaper first cost per horse power than the induction motors.

DO THE RESULTS WARRANT THE EXPENDITURE?

It has often been stated that the first cost of an electric plant, when added to that of the hydraulic or steam plant, renders its adoption undesirable, except in a few isolated cases. In other words, it is claimed that the first cost is so high that it does not pay.

In any other department of the mill the progressive and successful manufacturer does not hesitate to adopt new machines, or to substitute improved and modern devices, *provided* a fair return can be obtained either in quality or quantity. In the first place let us consider the operating expense. In this consideration let us drop all theoretical percentages except for interest, and be guided by *facts* obtained by experience.

Let us assume, for the purpose of illustration, a mill of 65,000 spindles, manufacturing standard sheetings, weighing 2.85 yards to the pound. Assume that each generator is coupled directly to a pair of water wheels operating under a head of about 36 feet, the power house being located in the neighborhood of the

FIG. 2.—ALTERNATING CURRENT GENERATOR.

FIG. 3.—INVERTED ALTERNATING CURRENT GENERATOR.

mill buildings. To drive and light this mill the wheels should be capable of delivering 3,000 horse power to the generators. The exact cost of such a plant can only be determined by a study of all the conditions. It would probably not in any case exceed $40 per horse power, or $1.85 per spindle.

The interest on this investment would be $2 per horse power per year.

Additional help might be required in the power house. The value of this labor would vary in each particular case, but it probably would not exceed forty cents per horse power per year. In the mill the shaft oilers can clean the motors and fill their bearings when necessary, but in connection with their other work.

The collecting rings on alternating current generators which have been in use seven years, show little or no signs of wear. If we assume, however, that once in ten years, these collecting rings will have to be removed, the cost per horse power per year will be three cents.

Assuming that the brushes will last only one year, the cost per horse power per year would be one cent.

The bearings are the only other parts, of either generators or motors, where repairs will be needed. These are self-oiling and consist of removable sleeves. Assuming that these sleeves will last but four years, the cost for renewal on the generators and motors would be seven cents per horse power per year.

To light the above mill there would be required about 1,500 incandescent lights, of which 500 would be of 20 candle power, and the balance of 16 candle power. Assuming that two-thirds of these lamps would be renewed each year, the cost per horse power per year would be eight cents.

The power house may be made fire proof, and if located away from the mill buildings, need not be insured. No fire can be caused from within the structure, and it would be so far removed from the other buildings, as not to be endangered in case of fire therein. The motors and inside wiring of the mill

should, however, be covered by insurance. Assuming that the rate would be four-tenths of 1 per cent., the cost per horse per year would be seven cents. For oil, waste and incidentals, we have allowed thirty-four cents per horse power per year.

Tabulating the above, we have the following as the total annual cost per horse power of operating the above electric plant for both power and lighting purposes:

Interest,	$2.00
Labor,	.40
Repairs,	.11
Lamps,	.08
Insurance,	.07
Oil, waste and incidentals,	.34
	$3.00

The above figures do not cover the cost of generating the energy delivered by the prime mover, as it is assumed that the amount of power required at the wheels would be no greater under the electric system than if the mill were operated mechanically. The purpose of the above estimate is merely to show any increase in the operating expense due to the adoption of the electric system, provided no economies are affected thereby. As stated, it covers the cost of operating the electric plant for *both* driving and lighting the mill. In making comparisons of the relative value of the mechanical and electrical systems of power transmission, it would be entirely proper to add the cost of lighting the mill to the operating expense of the former system. Thus if an isolated electric plant be used, its operating expense outside of labor and power would be twenty-five cents per horse power per year, based upon the power required to drive the mill. If gas costing $1 per thousand feet were used, it would require an annual expenditure of eighty cents per horse power on the above basis to light the mill equally well.

In a new mill, where there is opportunity to fully adopt the

principles above enunciated, there can be no question that advantages will be derived to fully warrant the installation of the electric system.

Referring again to the 65,000 spindle mill cited above, the annual operating expense, for both lighting and driving the mill, would be equivalent to an addition to the cost of the cloth of one thirty-eighth to one thirty-fifth of a cent per yard, or seven and one-half to eight and one-seventh cents per hundred pounds (depending upon the running time) or equivalent to fourteen cents per spindle per year. In either case this is less than one per cent. of the cost of the cloth. Oftentimes a reduction could be made in transportation expenses alone, of more than this amount, by reason of the freedom permitted in the selection of the mill site. The cost of teaming the coal, cotton, cloth and supplies which is often times nearly, if not quite, equal to this, could be saved by locating the mill beside the railroad.

In the case of the electric plant of the Pelzer Manufacturing Company, described below, the annual expenditure for coal required by the engine in No. 3 mill, amounted to about $10,000. Inasmuch as the steam for heating and slashing is supplied by boilers in No. 1 and No. 2 mills, the entire cost of the fuel now used in No. 3 mill will be saved by the substitution of the synchronous motor for the engine. This saving will more than equal the entire operating expense (including interest) of the electric plant driving both No. 3 and No. 4 mills and lighting the latter. In other words, the cost of power for these two mills, and the cost of lighting one of them would be no more than if the steam engine had been retained in No. 3 mill, and No. 4 mill had been located adjacent to the water power, and been driven therefrom mechanically. All of the advantages of concentration, subdivisoin, better transportation facilities, better light and ventilation are obtained without adding one iota to the cost of the cloth; these advantages must result, rather, in a very material reduction in such cost.

The saving in the costs of construction, when considered col-

lectively, will sometimes amount to very nearly the first cost of the electric plant. These savings would be made in the foundations of a mill located on solid ground as compared with the same mill erected beside a water power; in the omission of the canal; in the reduction in shafting and belting; in the construction of the buildings; in the omission of the belt tower; and in the lighting dynamos which would otherwise be employed. The value of this saving will vary in each case, and therefore no allowance is made for it in the above estimate. In applying the figures, the amount thus saved should first be determined and be credited to the first cost of the electric plant, and the item of "interest" (which constitutes two-thirds of the entire operating expense) should be computed only on the balance.

In the enlargement of a plant it is oftentimes impracticable, especially when driven by water power, to erect the new mill in close proximity to the buildings already constructed. As shown above, concentration of the manufacturing buildings is possible under the electric system. The additional cost of the labor required to run the mills when separated, as compared with the cost of the same mills when located together, may be considered as 5 per cent. interest on an investment. The amount of this investment will very materially assist in meeting the first cost of the electric plant. At all events, the value of the labor thus saved should be deducted from the annual operating expense as estimated above, in determining the comparative value of the mechanical and electrical systems.

A very small increase in the production will more than balance the operating expense of the electric plant. Where the above principles may be fully applied the result cannot fail to be favorable in this respect. On certain classes of work this increase in output is especially marked. In the printing room of the Dunnell Manufacturing Company, at Pawtucket, R. I., the electric drive was tried upon one machine. After three years' experience with individual engines on the balance of the machines (during which time a comparative trial was made of the friction

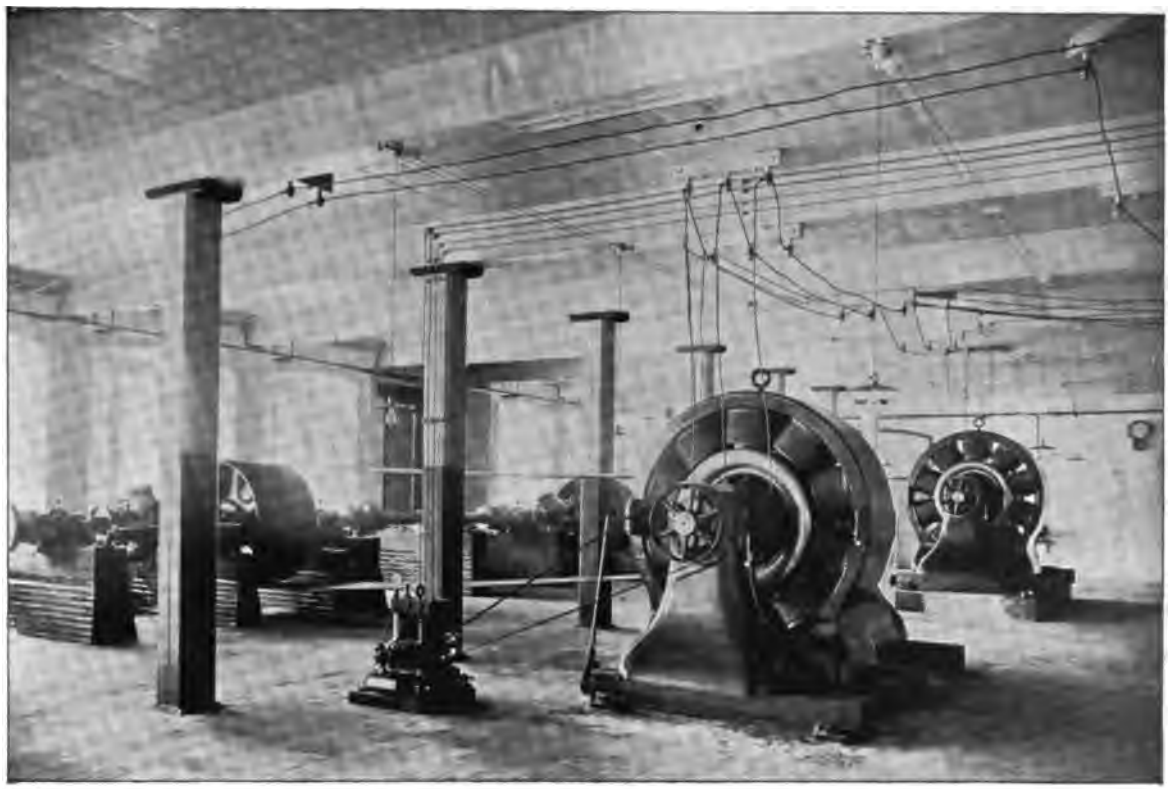


FIG. 4.—INTERIOR VIEW OF POWER STATION AT BALTIC.

cone) and after a previous experience with the single shaft and gears, the remaining nine machines were equipped with motors. The resultant increase of more than 25 per cent. in the output, without additional expenditure for labor or machinery, other than the electric plant, has fully justified the outlay. The quantity of seconds produced has also been reduced.

In mills already constructed, the electric drive may be profitably applied in replacing mechanical systems, in which by reason of turns or angles in the line of transmission, or of distance from the prime mover, much power is wasted. Buildings or rooms to which it is now impracticable to carry power, without great expense, may be utilized for manufacturing purposes. Such portions of the mill as are now operated overtime, may preferably be driven by electric motors and the balance of the shafting be stopped.

EXAMPLES OF THE APPLICATION OF THE ELECTRIC SYSTEM.

Having now considered the principles which underlie the electrical transmission of power, let us briefly examine a few of the cases which illustrate its special features.

The weave shop of the Ponemah Mills at Taftville, Conn., was formerly driven by a pair of Harris-Corliss engines, each driving one of the main lines of shafting. Four and a half miles away, at Baltic, was a finely developed but unused water power, also owned by the Ponemah Company. In 1893, the treasurer, Mr. E. P. TAFT, contracted for the installation of an electric plant consisting of two 250 kilo-watts triphase generators (each capable of delivering 330 horse power to the conducting wire), to be placed at the water power at Baltic, and for two similar machines, to be used as synchronous motors in the basement of his weaving building. The driven pulleys from the engines were placed upon sleeves, and the motors were connected by friction clutches to the main shafts. In addition to driving the looms, one of these shafts is belted to generators, which furnish current to the

Norwich Street Railway. An interior view of the power station at Baltic is shown in Figure 4.

The Columbia Mills, of Columbia, S. C., were the next to adopt the electric system, and the first cotton mill in this country, if not in the world, to depend entirely upon electric motors driven by generators located upon the premises, and also the first to adopt the plan of subdividing the mill into independently driven sections. The generating plant consists of two 500 kilowatt triphase generators (each capable of delivering 670 horse power to the conducting wires) direct connected to two pairs of 48-inch horizontal wheels. The mill is operated by seventeen 65 horse power induction motors. The mill building is placed upon a level plateau, some 40 feet above the canal where it receives the best of light, and where two competing railroads run their spur track into its yard. The power house is placed adjoining the canal and at the point where the greatest head of water could be obtained. The distance between the power house and the mill is comparatively short, not exceeding 700 feet, the conducting wires being placed underground. Since this plant was started, just a year ago, no trouble has occurred since the final adjustments were made, except once when a short circuit developed in the underground service, but was quickly repaired. A perspective view of the power house and mill is given in Figure 5.

Mr. C. K. OLIVER, treasurer of this mill, writes as follows under date of March 7, 1895:

"On the subject of our Electrical Power. I am much pleased to write that we are thoroughly satisfied as to its advantages and success as a system of transmission of power. We have been running very smoothly for about eight months. We have had no trouble from the system except one short circuit due to local causes, since removed. With that exception everything has been running along smoothly and continuously since starting, and we consider there is no question whatsoever as to its practicability and value in driving a mill. It is the neatest, cleanest, and to our idea the smoothest system of power one

FIG. 5.—PERSPECTIVE VIEW OF POWER HOUSE AND MILL.

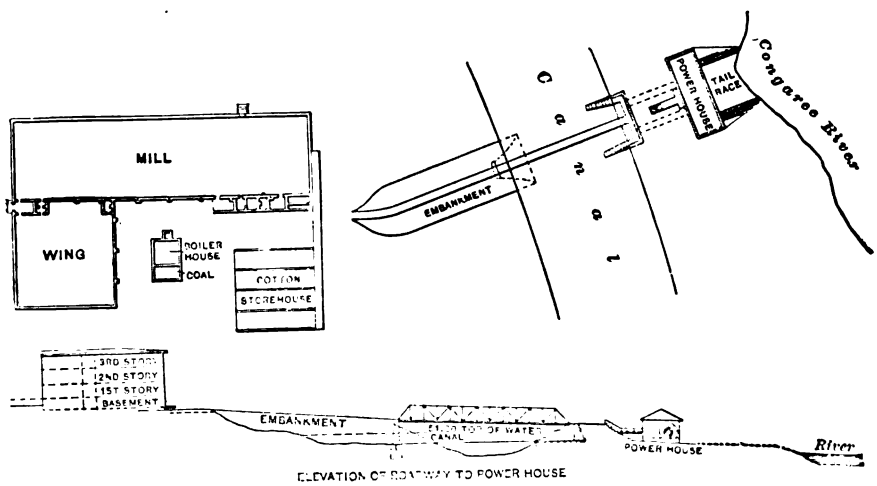


FIG. 6.—PLAN AND PROFILE.

could have, and we should not think of using any other system of power were we to fit up another mill.

"As our work is all coarse, and of a very heavy character, we require heavy machinery, and in any ordinary system of driving would require very heavy shafting, pulleys, belting, etc., while now we have very light shafting, no large pulleys and no belting wider than 12 inches, and this is a small one which we use on the exciter in the power house. Most of our belting is under 6 inches.

"In adopting the electrical power here, we were able to select the location for the miil with a view of obtaining the best light and ventilation, which we could not have done with the source of power located immediately in the mill building. We were also enabled to make our location convenient to the railroad.

"The uniformity of speed which we obtain from the electrical transmission enables us to get a great deal of product from our machinery, and consequently improved quality.

"In the matter of construction. The saving to us in the foundation work, shafting, belting, etc., has been considerable over what would have been necessary if the power had been located immediately under the mill, or if we had driven directly by steam. Another very important point to be considered is the fact that we are able to run sections of the mill without the necessity of running the shafting throughout the mill entire.

"Finally, we can say that we are thoroughly pleased with the system and would not change for any other that we know of."

The Pelzer Manufacturing Company, of Pelzer, S. C., was the next to adopt this plan of driving its mill by electricity. Their No. 1 and No. 2 mills were operated by water power, while No. 3 mill was supplied from a 400 horse power steam engine. Adjoining these mills was located the factory village, into which was run a spur track from the railroad some three-quarters of a mile distant. The company controlled several fine undeveloped water privileges, both above and below their present dams. Early in 1894, they decided to build another 55,000 spindle mill, to be operated from a power of some 5,000 horse power capacity, approximately three miles from their present village. After a very careful study of all the conditions, it was decided

to build the new mill adjacent to the other buildings, rather than beside the water power, and an order was placed for three 750 kilo-watt triphase generators (each capable of delivering 1,000 horse power to the conducting wire), each generator being direct connected to a pair of 39-inch wheels. A 400 horse power synchronous motor was also ordered to replace the steam engine in No. 3 mill, the driven pulley from the engine being placed on a quill. The new mill will be operated by twenty-three induction motors of from 5 horse power to 110 horse power capacity each, these being of the same general description as those installed in Columbia. Concerning the adoption of the electric drive, Captain E. A. SMYTHE, President and Treasurer of the Pelzer Company, writes under date of January 21, 1895, as follows:

"The advantages we obtain by the electrical transmission are many, including, if we had built the mill by the water power, the cost of canals, 45-feet stone foundations under the entire building, which is 505 by 128 feet, the cost of maintaining a railroad to the new mill, the saving of a duplication of our mill village conveniences, stores, schools, churches, lyceums, hall, offices, etc., and also the advantage of having the plant concentrated under the immediate supervision of the management. Another advantage was enabling us to select the site of the mill with a view of cheap foundations, location as to the points of the compass, which is very important, and a general convenience for the village and railroad."

If time would permit, many other instances might be mentioned, illustrating further the characteristics of the electric system. In several instances the electric motor has been used to supplement water wheels, the power required in excess of the capacity of the wheels being supplied by the motors; when thus connected, the wheel is set a little ahead of the motor, the latter furnishing the regulation. At other times where additional power has been required, the electric system has afforded an opportunity of using the same water twice, thus practically increasing the power of the stream. In other cases, the generator

may be driven by an engine previously running much below its rated load, and the power be distributed to remote sections of the premises, where it would otherwise have been necessary to have installed and operated a second steam plant. Sufficient, however, has been said to give in a general way the distinctive features of the system, so that any one familiar with power transmission can make application thereof to fit his own particular case.

Captain CHARLES H. MANNING. I thank Mr. PAINE for his account of what has been done as to the electrical distribution of power, and I am quite prepared to accept it as the very best solution of the subject in special cases; but how far these special cases may go to the solution of the general case, I think is still an open question.

There is no question that the first requisite is reliability and uniformity. Any distribution that lacks these points is going to be a failure. Now, whether the electrical distribution will give the reliability of the distribution at present in vogue, is a thing which, I think, wants to be considered. For instance, the question of the effect of lightning on the outside wires occurs to me. I should like to know from Mr. PAINE what provision is made to protect the apparatus against lightning. A delay of half a day in a mill is a much more vital question than whether the power costs one and five-tenths pounds of coal or one and six-tenths pounds. The loss when you stop that way cannot be recovered. The cost of attendance is another matter to be considered that enters with the electrical distribution to machines, generator and motor, both of which have to be cared for. Whether the care and cost of attendance is greater or less than the care and cost of operating with shafting and belting, whether the repairs on the new machines are going to be greater than

the repairs on the shafting and belting; these things have got to be considered before taking the electrical distribution.

Then there is another point—a possible call for an increase in the amount of power. We have very little trouble with our driving arrangements in our cotton mills, as they were designed at the start, but we keep adding machinery here and there until we are overloaded. Now that same loading will come no matter what the distribution.

Mr. PAINE. In reply to the questions raised by Captain MANNING, I would say that I understand that he makes the inquiries, not because he doubts the reliability of the electric system, but because he desires information. In regard to the question of reliability I would say that if we compare the conducting wires to the belt, I think there will be no question as to the greater reliability of the wire. If we compare the generators and motors with the shafting and belting, I think there is no doubt that the comparison will favor the former. Electric machines have been made for more than fourteen years, and the experience thereby obtained has been used in the construction of the later types. In so far as simplicity is concerned, generators and motors are far simpler than the steam engine with its many moving parts, yet you do not hesitate to trust your interests to an engine. Why then, should you hesitate on a far simpler piece of mechanism? The opportunities for break down are far less on the generators and motors than they are on an engine.

In regard to the interruption from lightning, I would say that suitable provisions have been made to prevent that. Street railways, although they have one side of their system connected to the ground, have very little interruption from lightning. In the system proposed in the paper under discussion, all connection to the ground is carefully avoided. By using barbed guard wire, grounded every fourth or fifth pole, the static tension in the neighborhood of the wires is relieved to a certain extent, on the same principle that the lightning rod acts. Our main

dependence, however, is upon suitably constructed lightning arresters, one of which is placed upon each wire at each end. Separate lightning arresters may also be provided as an extra precaution. I do not apprehend interruption in the service on this account.

In regard to the overloading of the system by increasing the machinery in the mill, I thank Captain MANNING for the suggestion on this point, which I did not enlarge upon in my paper. On a mechanical drive to get the increased amount of power desired, you oftentimes cannot increase the width of the driving and driven pulleys on account of the limited space, and you are obliged to put on a rider belt, which is a very objectionable feature. On the electric system, we have indicators which show the load, and consequently know how much power is being taken and how much more may be added. We are not, therefore, taken unawares in the increasing of the load. If you desire to enlarge your engine, you have to take it out and stop the mill until you can substitute another engine. On the electric system, where the generator is driven by an engine, if more power is required than can be given by the engine and generator already installed, we locate another engine and generator at any convenient point, and the old engine and generator run on as before. We place motors at the point where the increased power is desired, and connect these motors to the generator by wires which are run by the shortest practicable route. There is no interruption in the service; the mill runs on as before. When our new installation is completed, we start the new engine, generator and motors and use the increased power thus obtained. It seems to me, therefore, that the opportunity to provide against the overload appears to be in favor of the latter system.

Mr. A. F. KNIGHT. I notice that Mr. PAINE told us it required 2,000 horse power in the Pelzer Mill, and it occurs to me that we would run across the fact that that means about 34 1-2 horse power per thousand spindles. I would like to ask Mr. PAINE the amount of power at the power house.

Mr. PAINE. Please remember that in addition to the 2,000 horse power in No. 4 mill, we are to drive a 400 horse power synchronous motor in No. 3 mill, and operate 1,200 incandescent lamps in No. 4 mill. To supply this power, we have installed generators capable of delivering 3,000 horse power to the conducting wires, and have guaranteed that 80 per cent. of the power applied to drive the generators will be delivered by the motors, nearly three miles away.

In reference to the 3,000 horse power which I assumed was necessary to drive the 65,000 spindle mill used in my illustration, I am aware that this amount of power will probably drive a much larger mill under ordinary conditions. In order to be on the safe side, however, I assumed that the mill would have 65,000 spindles, rather than 75,000 spindles, and in determining the additional cost of the cloth caused by the adoption of the electric system, I made all my calculations in regard to the output of the mill on the basis of the smaller capacity. If that power would drive 75,000 spindles, instead of 65,000, then the additional cost of the cloth would be so much less. My purpose was to show the operating expense of a plant of the horse power named.

The PRESIDENT. The next paper is No. 11, "Generation and Distribution of Electric Power for Manufacturing Purposes," by Messrs. C. A. STONE and E. S. WEBSTER, Boston, Mass.

GENERATION AND DISTRIBUTION OF ELECTRIC POWER FOR MANUFACTURING PURPOSES.

MESSRS. C. A. STONE and E. S. WEBSTER, BOSTON, MASS.

The practicability of electric power transmission over distances up to, perhaps, twenty-five miles, can no longer be questioned. There are at present in the United States a large number of plants varying in size from one to five thousand horse power, which are daily transmitting power over considerable distances and giving good commercial service, with a reasonable expense for maintenance.

One of the principal questions of interest to the manufacturer to-day, is whether or not by the adoption of electric devices, in one form or another, he can effect a saving in driving the machinery of his mill.

Great zeal on the part of agents of electric manufacturing companies to sell their apparatus, has in the past led to somewhat exaggerated statements as to the economy which might be expected by the introduction of electrical machinery, and in some cases where the owners have been induced to install plants, under conditions for which the electric motor was not really applicable, the results have been disappointing.

Like other forms of mechanism, the motor has its place, and if properly designed and installed under conditions for which it is adapted, it always proves a factor of economy in the total cost of operation.

For short distances, where there is no serious objection to a mechanical drive, and when with no transformation whatever the power could have been transmitted directly with but a small loss, it is absurd to attempt to effect a saving by transforming power, already existing in the form in which it is to be used,

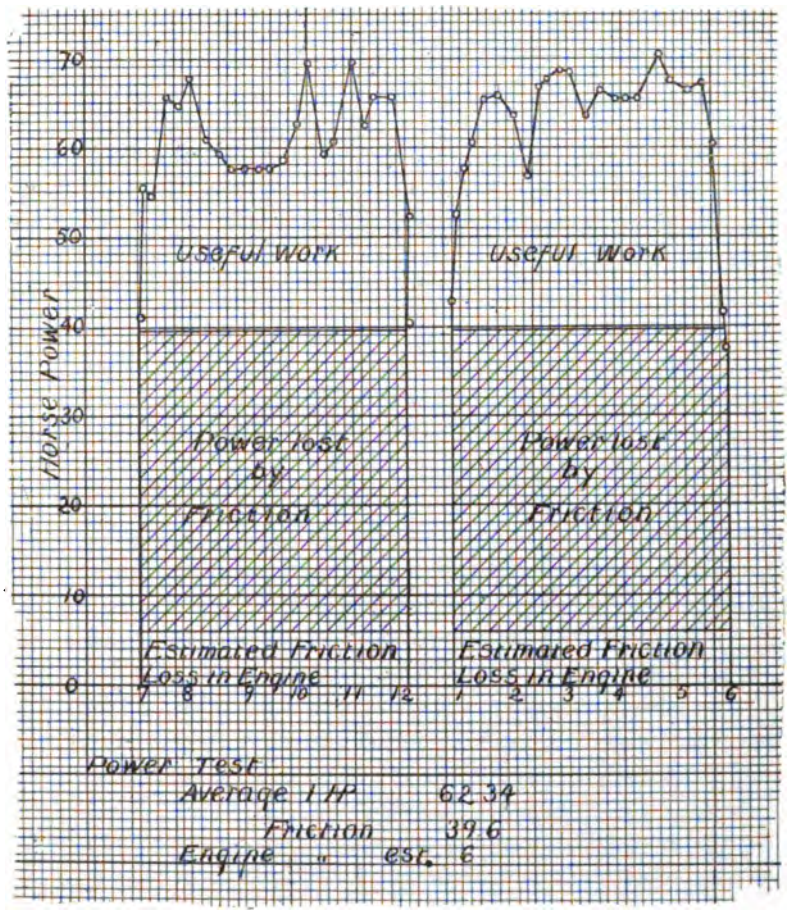
into electricity, and then retransforming this electricity into power again.

Theory teaches us through the laws of conservation of energy, that to create or destroy power is impossible, but that power is readily convertible from one form to another. Practice demonstrates that whenever a transformation of this sort is made a considerable portion of the available power is dissipated, either in the form of heat or in some other way, and the resultant energy falls short of the initial by an amount varying according to circumstances and conditions.

The science of thermodynamics shows us that with the most approved devices we are able to deliver in the form of power from a steam engine only about ten per cent. of the available energy which exists as heat units in the coal. The transformation of energy in the form of mechanical motion to electricity and the reverse, is accomplished with a comparatively small loss, but that such loss exists must not be forgotten, as it sometimes is, for the reason that it is not ordinarily evident to the senses.

This objection to electric transmission schemes holds good only in cases where electricity is used as a medium for transmitting power in bulk over short distances, say, from the prime mover, in whatever form it may exist, to lines of counter-shafting which are in turn used to drive the individual machine.

Many forms of machinery can now be driven directly by electric motors, and recent discoveries in electrical science and improvements in existing types of apparatus will probably before long make it possible to drive nearly all forms of mechanical devices directly by electric power without the use of counter-shafts. When this can be satisfactorily accomplished a great step in advance will be made, as a very considerable saving in power is obtained by this method, on account of the entire absence of the dead load occasioned by counter-shafting, and in addition to this greater convenience in manipulation is secured.



As illustrating the amount of power consumed in driving the shafting of an ordinary machine shop it will be of interest to refer to the accompanying curve, which shows the total horse power required in driving the machinery of an ordinary stamping mill. To obtain this curve, indicator diagrams were taken at the engine at various intervals throughout the day, and at noon when all the machinery was shut down, except the countershafting, a series of cards were taken to determine the actual

power required to overcome the friction, which, as can readily be seen from the curve, amounted to more than sixty per cent. of the entire work done. As a matter of fact, the actual average indicated horse power throughout the day was sixty-two and three-tenths, and the average friction load thirty-nine and six-tenths, including engine friction, which amounted to about six horse power. From this it will be seen that in order to furnish about twenty-three horse power to be used in actual work, it was necessary to produce over sixty-two horse power, including engine friction. Of course, no electrical method of driving would save the six horse power lost in the engine, but it is unquestionably true that a very considerable proportion of the remaining thirty-three and six-tenths horse power lost in shafting and belting could be saved by the direct application of motors to the machines themselves. Even allowing that in an electric transmission scheme of this sort, involving the use of small motors, an actual commercial efficiency of only 60 per cent. could be secured, still, we should be obliged to supply only forty-four indicated horse power, assuming the engine losses to be the same. This application of small motors directly to machines has been increasing considerably during the past few years, and there are now a number of manufacturing establishments where they have been introduced extensively.

Take, for example, the Pencoyd Iron Works of Philadelphia. This company has been gradually changing its entire transmission plant from mechanical to electrical methods. The power was originally transmitted by means of shafts and belts, but a trial was made of transmitting the power electrically, using a separate motor for each machine or group of machines, and the results were found to be so satisfactory from the standpoint both of economy and convenience, that at present the shops are operated almost entirely by electric motors. A total of over a thousand horse power, mostly in small motors, is now in use in this establishment alone. These range in size from one-half to fifty horse power, and are used to drive all kinds of machine

tools, drills, planers, shears, punches, milling machines, lathes, saws, cranes, hoists, roll tables, etc. In most cases the motors are connected directly to the machines without any belt, so that they practically become integral parts of the machines themselves.

The direct current motor has been largely used for purposes of this sort, and if properly designed, of sufficient capacity and run under a low voltage at a moderate speed, there is little objection to it.

The recent forms of alternating current induction motors which have been perfected, possess several decided advantages over the direct current type of machine, but they are still to some extent experimental, like other newly introduced apparatus. They are simple in construction and consequently less liable to injury and break-downs, and have no commutator, which is one of the principal sources of trouble in direct current motors.

Several of the smaller electric manufacturing companies are now devoting themselves almost exclusively to the manufacture of special motors to be applied directly to machines, and one company has recently built several motors to be coupled to silk looms, with arrangements for starting, stopping and controlling the speed by the simple motion of a switch.

Motors specially constructed for direct application to different forms of machinery require much thought and attention to build, and at best some experimental work is necessary to secure perfection in operation and control, but there are at least five well defined cases where electric power transmission can always be used to advantage with standard forms of electrical apparatus. These cases may be roughly outlined as follows:

1st. Where a large water power is available at a considerable distance from a mill which is in need of more power than can be obtained from the water privilege at the mill itself.

2d. Where, owing to the separation of mill buildings, it is desired to transmit power further than can be done by belting, in order to avoid the installation of individual steam plants in each building.

3rd. Where small water privileges are available at various points along a stream, but in order to become useful the power must be concentrated at one point without too great expense for maintenance and operation of the individual parts of the system.

4th. Where for various reasons in selecting a mill site it is desirable to locate at a considerable distance from the source of power, usually on account of the fact that the land immediately adjacent to the privilege is not suitable as a location.

5th. Where, for special reasons, it is important to do away with shafting throughout the mill, and to avoid on account of fire risk or other reasons the ordinary belt holes between floors.

With any of these conditions given, the question which most interests the manufacturer is, whether or not an electric transmission plant can be installed with thoroughly practical and well tested apparatus so as to fulfil the requirements imposed, and to give results which are commercially satisfactory. By commercially satisfactory results we mean that the apparatus must be capable of delivering power cheaper than it can be produced by steam on the spot, and that it must also be durable, so that it will not be subject to repairs and consequent interruption. That results can readily be accomplished is best demonstrated by the fact that there are in daily operation throughout this country plants which are fulfilling every requirement. Take, for example, the first case which we have outlined, in which a water power is available at a considerable distance from the mill where the power is required. There are, perhaps, fifty plants in regular operation in this country which fall under this head. At least six different systems of transmission are in use for work of this sort, and in places where plants have been properly installed each is giving good results. One of the earliest long-distance transmission plants of this sort which was equipped, was that built by the Westinghouse Company for the San Miguel Mining Company, at Telluride, Colorado. The distance of transmission is about fourteen miles, and at the time of our

examination of the plant about three years ago, some four or five hundred horse power was being transmitted from the power station, located in the valley at the base of one of the mountains of the San Miguel range, to the stamp mills, situated on the side of the mountain, about 13,000 feet above the level of the sea.

At the power house a Pelton water wheel is used, which is coupled directly to the generator, and a single stream of water directed against the buckets on the periphery of the wheel generates sufficient power to carry the machine under a load of 700 horse power without difficulty. The water is taken from a reservoir on the side of the mountain, 600 feet above the level of the power house, and is conducted down in a steel pipe on the surface of the ground.

The electrieal machinery is of the single phase, alternating type, and the motors, of which there were three at the time of our visit, ran synchronously with the generator, a small Tesla motor being used for getting the machine up to speed. The plant was then doing good service, and a few months ago Messrs. NUNN, of Telluride, two of the principal owners in the company, assured us that the system was still in most satisfactory operation, and that it was intended shortly to make extensive additions.

One of the earliest mill plants of any considerable size installed in New England was that which we designed for Messrs. S. D. Warren & Company, for the transmission of about 250 horse power from Saccarrappa to Cumberland Mills, Maine, a distance of about a mile. This plant has operated satisfactorily for the last five years, which is not true of many of the plants installed at so early a date. Perhaps this has been mainly because no attempt was made to introduce experimental apparatus, but existing types of machines were adapted to the case by the special method of installation adopted.

Recently a considerable number of plants have been installed by the larger manufacturing companies on the multiphase sys-

tem, in some of which induction motors have been used, and these plants in most cases seem to be giving very good results, although they have not been in operation for a sufficient length of time to enable reliable data to be obtained as to efficiency and reliability.

Admitting, then, that power can be transmitted satisfactorily, the next important point is the economy of the electric transmission. In the case of a water privilege at a distance, where the problem is to transmit power in bulk for a few thousand feet or more, the practical question is simply one of cost of power delivered electrically as compared with cost of power produced on the spot by steam. The cost of power delivered by the motors of course depends upon the value of the water privilege itself, cost of development, cost of electrical apparatus, size of unit in which power is required, and local conditions.

The cost of power as produced by steam depends upon cost of coal, quantity of power required, and whether or not condensing water is available. There are so many factors entering into any particular case of this sort that the general question, which is so often asked as to whether or not a power transmission scheme is practicable with a given distance of transmission, is impossible to answer off-hand and requires careful figuring to determine.

To get a general idea of the cost, let us take the case of a water privilege with 1,000 horse power available, situated at a distance of two miles from a mill where this amount of power can be used to advantage. We shall assume that the cost of power ready to be delivered to the dynamos is $12 per annum, including all charges for interest, depreciation, and attendance of the hydraulic part of the system. The commercial efficiency of transmission will not be far from eighty per cent., so that if we are to start with 1,000 horse power we shall not be able to deliver over 800.

The cost of electrical machinery for a plant of this size would amount to about $23,000, and the interest, depreciation, repairs

and supplies, may be conservatively estimated at $2,500 per annum.

The necessary pole line, wire, accessories, and labor of installation would cost about $13,000, and interest and depreciation on this should be figured at eight per cent., which gives an annual expense of $1,040.

One man will be required at either end if a ten-hour run is made, and two men if a twenty-four-hour run is made. In the first case the cost of attendance would amount to $1,200 per annum, and in the second case to $2,400 per annum. On the basis of these figures, which practice has demonstrated are substantially correct, we find that the cost per horse power delivered for the electrical part of the system amounts to $6.30 for a ten-hour run, and $8 for twenty-four-hour run, to which must be added $15 per useful horse power for the cost of the water power, making a total of $21.30 and $23 respectively for ten and twenty-four-hour runs.

These figures are unquestionably less than those at which steam power could be furnished, except under extremely favorable conditions.

It often happens that in a manufacturing plant the mill buildings are so far separated that it is impracticable to transmit power by means of shafting or belting, and in such a case it is often desirable to install an electric transmission plant, to avoid the necessity of placing separate steam plants in each building. Every mill owner knows that it is much more expensive to generate power in small quantities than in large, and consequently if all the power required for a large manufacturing estatablishment can be generated at one point and transmitted electrically to the various buildings in which it is needed, a marked saving can be effected.

In order to see approximately what can be done in a case of this sort, let us suppose that we have two mill buildings situated say, 1,000 feet apart, and that in one mill we require 500 horse power and in the other mill 100. Under such conditions the

ordinary custom would be to install separate steam plants in each mill, but if by generating all the power at one point, instead of at two, we can effect a sufficient saving to more than pay the interest, depreciation, and maintenance for an electric transmission plant, we can clearly effect a saving in total cost of operating.

With coal at $5 per ton, using a compound condensing engine, the extra cost per annum of generating 600 horse power ten hours per day over that of generating 500 horse power, would be about $1,400, whereas the 100 horse power alone could not be produced for less than $30 per horse power per annum or $3,000. We could, therefore, afford to pay $1,600 for interest, depreciation, and maintenance of a suitable electric transmission plant for delivering 100 horse power, without increasing our total annual operating expense. Careful figures show that the interest, depreciation, and maintenance of such a plant would not amount to over $800 per annum, so that this is evidently a case where an electrical transmission plant would effect an $800 saving to its owner.

There are many cases of mill properties, especially in New England, where small water privileges are available, varying in size perhaps from fifty to a hundred horse power or over. Oftentimes these privileges have been developed hydraulically, and were at one time used for manufacturing purposes, but have since been abandoned and are now idle. We have seen cases where privileges of this sort, available at a very small cost, are within a distance of one-half a mile from a large manufacturing establishment in need of more power, and still they remain unused because it is supposed that it will not pay to develop them electrically, on account of the fact that they are not of sufficient size to warrant keeping the necessary help at the power station.

That such properties can be made use of to great advantage has been clearly demonstrated by the successful operation of a small plant which we installed some three years ago for the Samson Cordage Company at Shirley, Massachusetts. This

company has a mill requiring some 200 horse power to drive, situated on the Nashua River in Shirley, and as the available water power at the mill site was only about 150 horse power, it was formerly necessary to supplement this by steam in order to obtain power enough to drive the machines. At a distance of about quarter of a mile up stream was another mill, now the property of the Samson Cordage Company, which was originally owned by the Shakers of the Shirley settlement, and operated as a cotton mill, but had some time before fallen into disuse. This mill has a water privilege of from fifty to seventy-five horse power capacity, and it was decided to install an electric transmission plant, with the idea of conveying the power to the cordage mill. The problem, accordingly, as it was presented to us, was to design and install a plant the dynamo of which should be readily controllable from the motor station, and which should be so arranged that the motor would drive on to the main shaft in parallel with the water wheel at the mill, contributing its portion to the whole amount of power required. A 500 volt system was finally decided upon, and a fifty horse power dynamo and motor installed at either end, with extra field wires leading from the dynamo to the motor station, so that the dynamo itself would be under control at all times of the man in charge at the mill. Further than this, an artificial load was provided which could be thrown in parallel with the motor or used to entirely replace it. With these precautions it has been found that the water wheel and dynamo require very little attention and that practically entire control is obtained from the motor end, where, by an adjustment of the field resistance of the dynamo, the motor can be made to contribute any amount of power to the main shaft from nothing up to full load. Further than this, in case of trouble with the remaining part of the driving system, which might cause an unduly heavy load to be thrown upon the motor and thus injure it, a provision was made for tripping a circuit breaker which cuts out the motor and allows it to come to rest, but at the same time throws in the artificial resistance

before mentioned, which brings an equal load upon the dynamo and prevents the racing of the water wheel.

In the case of this plant the only expense for the fifty horse power delivered, is that due to the interest on investment, depreciation, repairs, and maintenance. This amounts to less than $15 per horse power for the power actually delivered, and as steam power under existing conditions would at best cost $40 per horse power, the electric system under the conditions mentioned clearly effects a saving to the owner of $1,250 per annum.

We have now taken up three of the cases outlined where electrical apparatus can be installed without question and prove commercially satisfactory. The fourth case is where it is desirable to locate a new mill at a distance from a water power which it is desired to utilize. This is precisely similar to the first case, where the problem was to transmit a large amount of power from a distance to a mill, and the figuring which applied in that case will also hold good here.

The last case is that in which it is desirable to do away with the main line shafting as far as possible and drive the counter-shafts by motors.

Thc question of economy is not an important one here, as there must be special reasons for its adoption, either because the power is brought from a considerable distance, or that it is desirable to do away with belts and counter-shafts as far as possible.

The value of electrical systems of driving, in many cases, cannot be over estimated, as they possess many advantages outside of those mentioned which we have not at present the time to discuss. The new and improved forms of electrical machinery, principally of the three phase and induction types, give the development of this line of work a great impetus, and already very gratifying results have been accomplished in the case of several cotton mills and other manufacturing establishments.

We have now taken up a few of the more common cases

where in the present state of the art it is entirely practicable to attempt electrical transmission in various forms. Of course there are other general cases, and many special ones, where it is perfectly practicable, but those given serve as a general illustration.

The common idea that all electrical apparatus depreciates rapidly is a misconception, brought about by the fact that it has been very common practice to introduce apparatus before it was really perfected.

Well designed and constructed electrical apparatus of standard types is as durable and reliable as the best steam engine made, and when such apparatus can be used, a manufacturer need have no hesitation in investing as freely as in ordinary mechanical devices, with the assurance that ten years hence there will be nothing to regret.

The PRESIDENT. The next paper is No. 13, on "Humidifying and Ventilating Mills," by Mr. OTTO HOFFMANN of Manchester, England.

HUMIDIFYING AND VENTILATING MILLS.

MR. OTTO HOFFMANN, MANCHESTER, ENGLAND.

The subject of humidity in spinning and weaving, not only in Lancashire, but in all textile centres throughout the world, has recently attracted considerable attention, and, singular as it may seem, nowhere has the subject come more prominently to the front than in England, where a moist atmosphere prevails, more or less, all the year around. Now if in England, where the climate is damp and the temperature equable, humidifyers are found advantageous, how much more must the case be in this country, where the climate is much drier and subject to frequent and violent atmospheric changes, changes that disorganize the spinning and weaving throughout your mills.

In such a climate as exists in the United States an equable degree of humidity is more necessary than in any other country in the world, if the productions of your looms and spindles is to equal that of such a country as Great Britain. In dry and frosty weather it is well known that there is always some difficulty experienced in carding and spinning. Much of the trouble arises from the presence of a considerable amount of frictional electricity, caused by the speed at which machinery is now run, which is not only a source of great annoyance, but a positive loss to mill owners; then the dryness of the air in spinning and card rooms weakens and renders the fibre brittle, consequently humidity is necessary, both to strengthen the fibre and allay the electricity. The fact that frictional electricity is present is owing to dry air being a poor, and moist air a good, conductor of electricity. It is obvious that if the air of a cotton mill could always be maintained at a certain moisture, few troubles would ever present themselves, and you would get good spinning and weav-

ing, irrespective of the weather. The dryness and heat of mills is increased through being entirely closed so as not to admit the outside atmosphere, so that when the air is humid outside it only has a slight effect inside. To open windows is objectionable, as it causes drafts, injurious alike to the spinning and the work-people. I have found that in the average of mills tested (which is a considerable number), the degree of moisture in the spinning rooms is: In mule rooms, 40-50 per cent.; card rooms, 35-40 per cent.; humidity, relative dampness. This is 25 to 35 per cent. below what is necessary for good spinning.

During its manipulation, cotton loses heavily in weight. In the bale the average moisture is about 8 per cent.; in the cop the average is only 2 1-2 per cent. when it comes from the spindle; so that it is of great advantage to be able to retain the natural humidity throughout the process of spinning. Many appliances have been in use for maintaining the relative humidity in mills, but hitherto none have proved successful. Steam has been the agent employed to obtain artificial humidity, and it is said to have been introduced into England from this country some 40 to 50 years ago, so that the United States may claim to be the inventor of humidification; but steam has had its day and is fast dying out, not only in England, but on the Continent. The operatives who have to work in the mills have now come to have some say as to the means that shall be adopted to produce humidity. In my experience—and it is a very extensive one—I may say that the operatives are entirely opposed to steam and before long will agitate for its total abolition. Personally, I have the strongest objection to steam, and I know of no cases now where its use is a necessity. Live steam increases the heat, it damages the buildings and machinery, and is proved by the most conclusive medical evidence to be deadly unhealthy. Operatives who work in a steamed atmosphere carry their lives in their hands, and are either quickly killed off or permanently disabled by rheumatism. It is therefore undesirable from every point of view. I may mention here a report of Dr. LETTS, D.S.,

Ph.D., of Belfast. Search made of the number of micro-organisms in the external air and of a steamed weaving shed:

MICRO-ORGANISMS PER LITRE OF AIR.

External air—Micro-organisms 2; Moulds 0; Total 2.
Air of weaving shed humidified by steam — Micro-organisms 65; Moulds 22; Total 87.

The quantity of air drawn through the tubes was, in all these experiments, two litres. The number of micro-organisms in the tube from the steamed shed were so numerous that I could not count them properly. The above is the minimum number.

It is not my object to give you a lecture on the advantage of humidity, as from my experience and what I have read in your papers and such able treatises as those of Mr. GARLAND and Mr. STURTEVANT, I am sure you are all well aware of its necessity. It is rather my desire to bring to your notice an improved method of moistening and ventilating textile mills. I refer to the drosophore system. It is one that, although only introduced some two years ago, is already more largely in use in Great Britain, on the Continent, and in India, than any other, and as soon as you realize the benefits to be derived from this system, as we have done, I am sure it will be quite as largely adopted here. Having been connected with the textile mills over twelve years, I have given much attention to the subject of humidifying.

One of the systems I became acquainted with was the aeropher, [Messrs. Trentler & Schway, Berlin, Germany], which, I believe, is worked in this country by Mr. GRINNELL or by a company. This apparatus was later introduced into Great Britain. Theoretically, it worked perfectly, and when the cost of installation and expense of attention, maintenance and pure water were no consideration, it did well. I am very sorry to say that it failed in Great Britain and on the Continent because of the cost and the trouble and annoyance caused by constantly stopping up. Another system, or, as we may call it, humidifier or atomizer, that has failed is the Tattersall, constructed on the same

principle is the Garland Humidifying System. This failed because the desired degree of humidity could not be obtained even in Great Britain's moist climate. Knowing all systems of humidifying and aware of their defects, I started to construct a new humidifier, called at present the drosophore (Drosophore is a Greek name; translated into English it means "dew-bringer"), which would overcome all defects and would be offered at a price that put it within the reach of all. That this construction has proved a success, I am very glad to say is amply proved by the sale of the enormous number of over 12,000 drosophore machines in a little over two years, in spite of the most disastrous period the textile trade has passed through. I can assert, without fear of contradiction, that the representative textile mills in Lancashire, Yorkshire, and other parts of Great Britain, the Continent and India have adopted it, and in many cases it has replaced large and expensive installations of other makers, so that to-day it is practically the only humidifying and ventilating system that is on the market. I just left the Continent. I have been in Mulhouse, Alsace, Germany, and took a pretty large order of a humidifying and ventilating installation. It is quite a new mill in course of construction, and will be ready for the drosophore installation in September or October this year. The mill will be built after the English style. The most gratifying feature is that we are constantly in receipt of large repeat orders. Where a few were tried in the first instance, the benefits were quickly appreciated, and orders given for the entire mill.

The drosophore is an apparatus for moistening and ventilating the air in textile mills by means of an excessively fine water spray that is absorbed by the atmosphere, so that a suitable and equable degree of humidity is maintained under all conditions. In summer the temperature is reduced by using cold water, and by warming the water in winter it assists in maintaining the temperature. As the entire air of the spinning or weaving room is passed through the drosophore machine very often more than

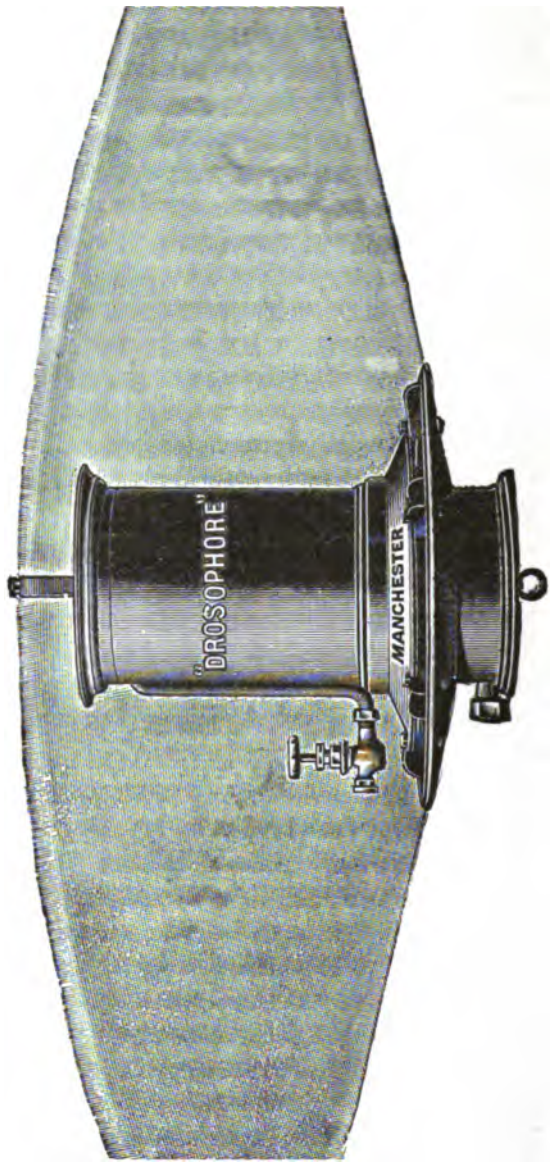


FIG. 1.—THE DROSOPHORE.

once per hour, it is thoroughly washed and purified and rendered as fresh as out of doors.

The spray nozzle is a very ingenious invention. It consists of a means of utilizing the force of two opposing streams of water, the one ascending, the other descending. These opposing streams of water are so arranged as to be exactly opposite each other, but the lower one being a little smaller than the upper one, the result is that the water under pressure, travelling at a high velocity, is forced through the nozzle and the impact of these streams pulverizes the water into the minutest particles, so that the air absorbs them and there is no deposit to injure the machinery. There are no wearing points in the nozzle, as the streams of water come into contact with each other. No other humidifier possesses the double nozzle. They mostly employ single nozzles, or other appliances where the stream of water is striking against a solid pin, which is quickly worn away or out of shape, and the moisture produced is coarse, so that it falls immediately around the machine and wets the machinery.

A single nozzle can only produce one-third the air current of the double nozzle, so that the effect is very small, and an enormous number of machines would be necessary to produce any effect whatever; therefore, the cost of an installation and the expense of operating make it prohibitive. We in the first instance used a single nozzle, the best on the market, and still manufacture single nozzle humidifiers where a very small amount of humidity is required, but for general use it has been discarded in favor of the double nozzle, which has proved so much more effective. The nozzle is placed in a cylindrical casing of special construction, open at the top and bottom. Unlike other humidifiers its air is drawn in at the top and dispersed by an orifice round the bottom of the apparatus fully saturated. The air current and the water spray travel in the same direction and the large drops do not fall back as in those that discharged at the top and impeded the free current of air.

The effect of the double nozzle, combined with the construc-

FIG. 2.

tion of the machine, is such that three times more moisture and of a finer texture is produced and dispersed over an area three times larger than any other similar humidifier. As air can only absorb a given quantity of vapor per cubic foot, it follows that if three times more air passes through the machine, it absorbs three times the amount of vapor. It is hardly possible to give a fixed idea of the capacity of the drosophore machine, without considering the room where the drosophore has to be placed, and the kind of work carried on in it. Here, in your country, roughly it may be estimated that one machine is required to from 10,000 to 40,000 cubic feet of air per hour; for mule spinning American cotton, 25,000 cubic feet; Egyptian or Sea Island cotton, 20,000 cubic feet; for ring and flyer spinning, 20,000 cubic feet; worsted or wool spinning, drawing, combing, 17,500 cubic feet; weaving cotton or wool, 20,000 cubic feet; silk flax, jute spinning and weaving, 12,500 cubic feet; conditioning rooms 10,000 cubic feet of air per hour to obtain the desired humidity for its purpose.

You will see by the plan before you that the drosophores are

placed at equal distances apart, according to the number. For hot rooms that require the temperature reduced, we use the drosophore ventilating machine, admitting fresh air and moistening about 40,000 cubic feet of air per hour. Fans are placed on the opposite side of the room to discharge the vitiated air.

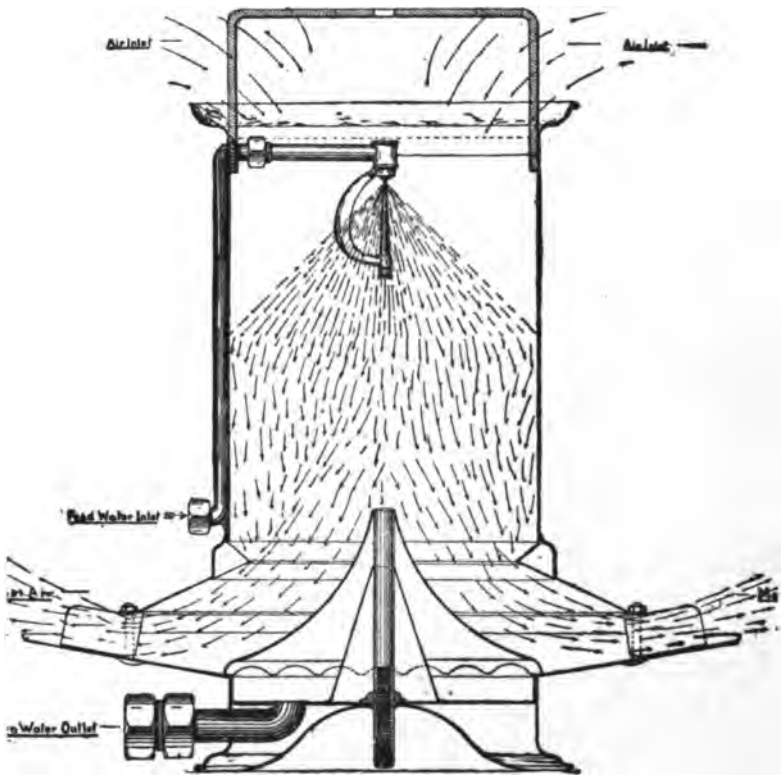


FIG. 3.—THE DROSOPHORE.—SECTIONAL VIEW.

As a general rule we recommend ventilation, especially in summer weather. The air of card rooms should be changed twice or thrice per hour, and of spinning and weaving rooms once per hour. As the heat of woollen rooms is not so great, the change of air may be once or less per hour. Flax spinning requires a

large amount of ventilation on account of the dust, but when the drosophore is in use, the moisture lays it to a very considerable extent.

Silk, owing to the high degree of humidity necessary to produce the best results, does not admit of much ventilation, and fresh air should be obtained by the use of the ventilating drosophore. The drosophores are connected together by means of galvanized wrought iron pipes of small diameter, the size of pipe depending upon the number of drosophores.

The upper one is for water pressure to supply the machine, and the lower one for water that runs to waste, which is returned to a tank from which the pump takes its supply. With reference to the plan shown, it will be seen that all the rooms are connected with the tank, which should be situated in the lowest point of the mill. The water pressure may be obtained direct from the town or private supply when the pressure is 100 pounds per square inch, but as each machine uses sixty gallons of water per hour, of which two gallons — 14,000 grains of water is dispersed into the air, and the remaining 58 gallons run to waste— it is generally more economical to use a pressure pump, either steam or belt driven, and use the return water over again. The drosophore system is extremely simple and easily operated and requires little attention.

The cost of maintenance is practically nil. It is unquestionably *the* system, not only of the day, but of the future, and I see no reason why it should not be generally adopted throughout the textile mills of this country. It will place you on the most favorable conditions for spinning and weaving, and every day will be a good day.

During the oppressively hot days of summer it will render the mills the most pleasant place to be in. It will invigorate your work-people, improve their health, and render them able to turn out more work. Your production, at present considered high, will be overshadowed and left behind; you will spin better yarn and weave better cloth, and with the energy and intelligence

you have in this country, with an enormous population and cotton at your doors, I think in the future, when the disadvantages you suffer from your drier atmosphere are overcome by the free use of the drosophore system, you will become the greatest manufacturing country in the world.

At the conclusion of reading the paper, Mr. HOFFMANN gave an illustration of the operation of the drosophore.

The PRESIDENT. The next is Topical Question No. 26, "English practice has been in the direction of separating the business of spinning from that of weaving. What are the advantages of this separation? Is there any tendency discernible in American practice at the present time?" [No discussion.]

The PRESIDENT. The next question is No. 27, "With conditions and appliances favorable to the maintenance of uniform steam pressure at the cylinder, how close ought a first-class steam engine to keep to standard speed in driving a cotton mill?" [No discussion.]

The PRESIDENT. The next question is No. 28, "The English time-table for 56 1-2 hours per week divides the working day into three parts, with an hour for breakfast, and an hour for dinner. What advantage has the plan over the American system?"

The PRESIDENT. The next is No. 29, "How can the superintendent or manager of a mill best get at the sentiment of his employees upon matters of reform or wages?"

Mr. A. H. LOWE. When I read this question on the programme, I said it was not broad enough. A large proportion of the cost of goods goes to the employees. They are sensitive and sometimes their views are very difficult to get at. This question as it is put, brings the Association to a discussion of how you can reach them to get their ideas, whether it be in regard to wages or to some reform. And it brings up the question of textile unions and other organizations. It goes into the question of whether there is not some other way to get at the feelings of the help. It brings up the question whether you could reach the help through a committee asked for by the employee. We have been going through some pretty trying times for the manu facturer and the employee. It is pretty hard for the employees to accept a reduction in their wages, and it is just as hard for the manufacturer to be obliged to reduce his labor. You can, of course, reach your help through your overseers; but whenever an overseer is sent to inform the help that a reduction is to be made, a feeling is created that the overseer is on the side of the employer, and of course there is a line drawn between the overseer and the employee. It seems to me that this is a subject for careful discussion.

Mr. T. B. MOLE. Mr. President, the nearer we get to results in this matter without having trouble, the better. Then we want to avoid this trouble with the help. Have the committees so as to get into close contact with the people in regard to the questions coming up every day.

Mr. R. W. EATON. Mr. President, I wish to talk a moment on this question. Absolute monarchy is called the ideal government, provided the monarch is an ideal monarch. Absolute monarchy is the best method in a mill, if the manager is the ideal man for it. The matter of the overseer was mentioned, and that people think that the overseer is on the side of the manucturer, and not the help. Now, the overseer is the servant of the manager, or agent, of the mill. He is in the mill to carry out the orders of the agent or manager, and under no condi-

tions should we allow the overseer to settle the troubles with our help. In the little experience I have had, the great trouble has come from overseers, because an overseer may take advantage of the little power that has been given him to impress persons who, perhaps, are fully as intelligent as himself.

The PRESIDENT. The next question is No. 30, "Tare on cotton. Is it not excessive? Can agitation among manufactures have any effect in reducing weight of hoops, sacking, etc.?" [No discussion.]

The PRESIDENT. The next question is No. 31, "Is a scutcher in a finisher picker of as much benefit towards making good, strong yarn as a licker-in on a card?"

Mr. E. A. LEIGH. Mr. President, some years ago the "express" card or beater came before the manufacturers with jubilant promise of a complete revolution in the picker department. Many were introduced, but all found unsatisfactory, and I know of only one working at the present time. As many of you know, the machine was built similar to a scutcher, in regard to the feed part, cages, fan, and lap part, but differed in that in place of the beater it was supplied with two cylinders of different diameters and running at different speeds. The larger cylinder was covered with Garnett wire and was placed in the same position as the beater of a scutcher, taking the cotton from the piano holders and feed roller in precisely the same manner. The smaller cylinder was placed below and was covered with ordinary leather takerin card wire, which cleared the larger cylinder, throwing the cotton on to the grate bars in the same manner as an ordinary scutcher. The inventors, Messrs. RISLER and LORD, only claimed to obtain a production of carded lap of about two-thirds of the amount of an ordinary scutcher, but they also claimed the better freeing of the cotton from leaf, and the saving of much stripping and brushing out in the carding engine, the

improving of the carding and an increased production therefrom, as the fibres had been previously laid parallel and cleaned by the "express," etc. The results showed that however parallel the fibres might have been laid by the "express," when they were thrown upon the cage they scattered again in all directions. The staple of the cotton was cut and made very nappy, so much so that it was much more difficult to card; besides, the cylinders broke up the leaf, rendering it difficult to get out afterwards. All this tends to show that the carding process ought to be done in the card, where the construction of this machine is most favorable for this purpose.

The PRESIDENT. It has been suggested that we close the morning session now, as some of the members would like to go to the hotel. Everybody will take the electric cars, ladies and all, from the front of the hall at one o'clock.

EVENING SESSION, APRIL 25, 1895.

The PRESIDENT. The report of the Committee on Equitable Payment of Prices for Weaving Various Styles of Goods, Messrs. E. W. THOMAS, Lowell, Mass., and A. F. KNIGHT, Manchester, N. H., is in order.

REPORT OF COMMITTEE "ON THE EQUITABLE PAYMENT OF PRICES FOR WEAVING VARIOUS STYLES OF GOODS."

Gentlemen—The Committee have spent considerable time in investigation of the subject and beg leave to report that the broad field and limited time at their disposal render it necessary for them to suggest that the question be postponed until the fall meeting, as the subject is one too comprehensive to have prepared a paper or report for this meeting that they feel would be of any material benefit. They therefore trust that this report be accepted and the suggestion embodied therein be adopted. Your Committee, however, have decided to present to the attention of the members the text of the Blackburn list, so universally in use in the plain weaving districts of England. This list was originally prepared in 1853, and is to-day practically adopted. The manufacturer to-day who is catering for the market, and on contract work, and who makes frequent changes in the running arrangement of his looms, is frequently at sea in fixing prices for weaving of some new fabric to him, that will be fair to the weaver and to himself. A careful study of the list may enable many of you to offer suggestions tending to the modification of the list to meet our American practice.

Your Committee, in conversation with many manufacturers, has been strongly impressed that some good practical system is needed, and if they are fortunate enough, or, perhaps, unfortunate enough, to be reappointed, they will be sincerely pleased to obtain the views of any one who has made this matter a study.

THE BLACKBURN LIST, 1853.

1st. *The Standard.*—The standard upon which this list is based is a 40-inch loom, weaving from 36 to 41-inch cloth; 60 reed, 64 picks per inch, 30's to 60's warp, 28 to 45 filling, 37½ yards, for 12.25d or about 24½ cents United States money.

2d. *Reeds.*—A 60 reed or 30 dents, being the standard is made the starting point, and three-fourths per cent. is deducted for every two ends or counts of reeds from 60 to 48; but no deduction is made below 48 reed; and three-fourths per cent. is added for every two ends or counts of reed above 60.

3rd. *Filling.*—All filling from 30's to 60's, both included, is considered medium, and reckoned equal, but all filling above 60's to be allowed 1 per cent. for every ten hanks, and all below 30's to 26's be allowed 2 per cent. on list. All below 26's to 20's to be allowed 5 per cent.; all below 20's to 16's to be allowed 8 per cent.; all below 16's to 14's to be allowed 10 per cent.

4th. *Warp.*—All warp from 27's to 45's, both included, is considered medium and reckoned equal, but all warp above 45's to 60's to be allowed 1½ per cent., and all above 60's to be allowed 1 per cent. for each ten hanks; all below 28's to 20's to be allowed 1 per cent. on list; all below 20's to 14's to be allowed 2 per cent. on list.

5th. *Addition for Picks.*—All picks above 32 and up to 72 are considered proportionate, but 32 picks and all below, and all above 72 to have 1 per cent. allowed for every pick over and above the proportionate difference in the number of picks.

6th.—*Width of Looms.*—A 40-inch loom being the standard

is taken as the starting point, and all additions or deductions are made therefrom.

26-inch loom has			2½	per cent.	deducted	from	30-inch loom.			
30	"	"	5	"	"	"	35	"	"	
35	"	"	5	"	"	"	40	"	"	
45	"	"	5	"	added	"	40	"	"	
50	"	"	10	"	"	"	45	"	"	
55	"	"	10	"	"	"	50	"	"	
60	"	"	10	"	"	"	55	"	"	

7th. *Looms of Intermediate Width.*—One per cent. per inch to be deducted down from 40 to 30-inch loom; below 30 to 26-inch loom five-eights per cent. per inch to be deducted. Above 40-inch up to 45-inch loom 1 per cent. per inch to be added, and all above 45-inch 2 per cent. per inch to be added.

8th. *Narrow Cloth in Wide Looms.*— Suppose a 40-inch loom should be weaving cloth 36 to 31¼ inches wide, take off one-half the difference between 40 inches and 35 inches loom price; and if weaving cloth 31 to 27¼ inches wide, take off one-half the difference between 40 inches and 30 inches price; or, if weaving 41¼ to 46-inch cloth in a 50-inch loom, take off one-half the difference between 50 inches and 40 inches loom, and so on with other widths.

9th. *Range of Cloths.*

26-inch loom			allowed	to	weave	cloth	up	to	27	inches.
28	"	"	"	"	"	"	27	"	28	"
30	"	"	"	"	"	"	27	"	31	"
35	"	"	"	"	"	"	31	"	36	"
40	"	"	"	"	"	"	36	"	41	"
45	"	"	"	"	"	"	41	"	36	"
50	"	"	"	"	"	"	46	"	52	"
55	"	"	"	"	"	"	52	"	57	"
60	"	"	"	"	"	"	57	"	62	"

10th. *Adding or Deducting Percentages.*—In making calculations the allowances must be added or deducted separately, in the order they are here placed, viz.: reeds, materials, picks and widths.

11th. The discount now accepted is 10 per cent.

Example.—To find price for a cut of 44-inch cloth in 45-inch loom, 66 reed, 48 picks per inch, 75 yards long, 34 warp, 36's filling.

	24.50c standard.
Add 2¼ per cent. for reed,	.54
	25.04c
Add 5 per cent. for width of loom,	1.25
	26.29c
Calculate proportion of picks 64 to 48,	19.72
" " length 37½ to 75 yards,	39.44
Deduct 10 per cent.,	3.94
	35.50c per cut of 75 yards.

The list has a large number of tables to be used for reference, all worked out on the system and basis as specified in the text before mentioned.

EDWARD W. THOMAS.
A. F. KNIGHT, } *Committee.*

April 24, 1895.

The PRESIDENT. The next paper is No. 14, "The Principles of Construction of Card Clothing, by Mr. JOSEPH NASMITH, Manchester, England.

THE PRINCIPLES AND CONSTRUCTION OF CARD CLOTHING.

MR. JOSEPH NASMITH, MANCHESTER, ENGLAND.

Although it is admitted that no accessory used in cotton spinning plays so important a part in the economy of the industry as card clothing, it is somewhat remarkable that the average spinner knows less of its construction than of almost anything else in the whole range of the appliances with which he deals. When the writer received the flattering invitation of your secretary to communicate something in the way of a paper to the present meeting, it so happened that he had just terminated a long investigation into the construction of card clothing, and, while disclaiming any right to be considered an authority, thought that something might profitably be said thereon. The subject is one of great complication, and it is rendered the more puzzling by reason of the variation in practice which prevails among different makers, there being apparently no definite rule by which the matter is governed. What the writer desires to do, therefore, is to endeavor to deduce from the facts at hand the points which it is desirable to know in judging card clothing and the principles underlying its construction. As the matter at present stands every spinner knows that with a certain make of clothing he gets a good result, and with that knowledge he is content. If anything goes wrong he is utterly helpless to locate the fault, although it may be found lying on the surface. Although it is neither necessary nor desirable that all the minutiæ of the construction of card clothing shall be known to the spinner, it is surely better that he should have sufficient knowledge to discriminate between good and bad, or suitable and unsuitable.

There are many factors which affect the selection in a matter

of this kind. Of these may be named the character of the carding machine employed, the character of the cotton used, the quantity of cotton which it is desired to pass through the machine weekly, the position and location of the mill, and the quality of carded web desired. It is not possible to discuss at all profitably all these points, and it will be necessary to confine attention to one or two.

It will be assumed that the only two classes of cotton which need to be considered seriously at present are the average quality of American and Egyptian. The general characteristics of the two products vary somewhat within well defined limits, Egyptian cotton being finer and longer, cleaner, and more regular in staple than the best American grades. One of the results of these differences is that Egyptian cotton is mainly used for that class of yarns which are intended to be of superior quality, and in the preparation of which greater care can be bestowed. Further, the quantity of short fibre, leaf, mote, and the like, is much less than in other cotton, so that there is not the same provision necessary for its reception. How this bears upon card clothing will be seen hereafter, but in the meantime it is sufficient to note the fact. The broad distinction between the two cottons, from a carding point of view, is mainly that arising from the fact, that the one is devoted to the production of a yarn of a high quality, which requires and receives great care in its manipulation, and the price of which is such as to justify this treatment; while the other is used for yarns which are employed in the manufacture of goods the price of which renders a large production imperative for economical reasons. The ultimate end fixes the procedure, which may be broadly put that, given the same type of machine in each case, the quantity of output must, of necessity, be widely different. It need hardly be said that even spinners of Egyptian yarns would, if they could, increase the output of their carding machines, but when they do they find the result is not satisfactory. The writer is acquainted with many cases in which the experiment of increased output

has been tried with the result, that sooner or later—generally sooner—a return has been made to the old speeds. So far as American cotton is concerned, however, the tendency in England, at least, is to pass a great weight through the machine, and, at the same time, to produce a web of a satisfactory character by one carding. It is obvious that we have here a different set of conditions and one which necessarily has a great influence upon the clothing used.

What is the object of carding? It is to remove from the cotton, fibres of less than normal length, neps, leaf, broken stalk, and all the lighter impurities left after picking. If the character of the work done by each of the separate working parts of a carding machine be considered, it will be seen that the heavier impurities are removed by the mote knives and licker-in, and that the function of the wire teeth on the cylinder and flat, or rollers, is to remove or retain the short fibres and neps. The fact being thus stated it becomes at once obvious that the receiving capacity of the clothing must necessarily be proportionate to the weight and cleanliness of the cotton dealt with. A second object aimed at in carding is the placing of the fibres in the web in at least approximately parallel order. This implies some action in the nature of combing, and is largely affected by the quality of cotton passed through the machine in a defined period. It is obvious that if a carding engine cylinder is so lightly supplied with cotton that there is only one fibre for every four carding teeth, as Mr. B. A. DOBSON puts it, each fibre is manifestly in a position to be treated individually, a condition which could not obtain if, for instance, the relation were reversed. In theory at least this individual treatment is what is required, and in all flat carding machines, whether the flats be revolving or fixed, the idea of combing each fibre underlies the conception of carding.

It is not, however, the purpose of this paper to deal with the theory of carding further than as it affects the action of the clothing, and what has hitherto been said has been for the pur-

pose of clearing the ground. The application of the demonstrated facts will be made as the various points arise.

In all card clothing there are several points which affect the general result. Of these the principal are:—

(1) The character of the matrix or foundation receiving the teeth.
(2) The character of the wire as to shape, material, and preparation.
(3) The angle at which the wire passes through the foundation.
(4) The angle of the forward inclination given to the tooth from the bend.
(5) The relative height of the bend and point.
(6) The size or thickness of the wire used.
(7) The setting of the teeth in the foundation.

Taking these points as they arise, and dealing first with the foundation, it is essential that the cloth from which this is made shall give, when the various layers are put together, a firm base capable of being tightly laid upon the surface which it has to cover without unduly stretching or disturbing the setting of the teeth, and giving an elastic but firm support to them during work. The favorite foundation in England consists of three or four plies of cotton and wool or cotton and linen, or union cloth, with a top facing of natural india rubber. For cylinder and doffer fillets, a foundation of three plies of cotton and a ply of union, linen warp, and cotton filling, cemented together and faced with india rubber, makes an excellent foundation for such numbers as are ordinarily used for carding American cotton. The india rubber face has the disadvantage that, under conditions of excessive heat and even long use, it disintegrates, and it would be of interest if any of the members of the Association wonld state their experiences with this material. Its wide adoption and use alike in England and the Continent of Europe can only be explained on the ground of its suitability for the work under the conditions there prevailing. The advantage of a rubber face is that, at the point where the tooth is pushed back, an elastic support is given to it which permits it to yield,

while exercising a certain resistance which brings the tooth up again. For the clothing used for covering revolving flats india rubber is never employed, the reason being that for a great part of the working life of a flat it is turned face up and is exposed to the direct rays of the sun, if such enter the room, it being also necessary to hold the teeth firmly yet flexibly.

The number of separate layers in the foundation used varies, of course, with the work to be done, finer counts of wire doing lighter work being permissibly placed in a lighter foundation. For ordinary work it may be taken that not less than three plies should be used. An excellent combination, which gives the best results, alike as giving to the tooth a firm support and an elastic bed, is that of an upper and lower layer of twilled cotton cloth with a double thickness of woollen between. The twilled formation of the foundation cloth gives it a firmness which is not observable in a plain fabric, while the presence of the wool gives a soft but all-round grip which holds the tooth excellently. It is, however, necessary that the woollen cloth shall be well made and compacted. The various layers of cloth, whatever they may be, should be cemented and pressed together so as to form a well-compacted matrix in which the teeth can be set. It does not matter so much how the foundation is built up provided that the necessary firm but flexible hold be obtained; but the cotton-wool-wool-cotton combination, where flexibility and elasticity are of principal importance, is bad to beat. The importance of the matter lies in the fact that if a tooth is too rigidly held it is liable to be cranked back at the point where it leaves the foundation, or it may, if hardened and tempered, break off entirely. The desideratum is a foundation which will wrap well on the cylinder, doffer, rollers, or flats, and will not afterwards yield under the ordinary conditions of work. It must be strong and flexible, and be able to grip the wire with sufficient firmness while having the quality of recovery after the teeth have been moved in the process of work or grinding. Fortunately it is hardly necessary to take any precautions against defective foun-

dations, as it rarely happens that these are made; but it is not a difficult matter to discover if they are, although some trouble may arise in consequence before the fact is ascertained. In spite of the variety which exists in this matter, the general result is satisfactory. Taking as typical a foundation common in England for cards which produce 800 to 1,000 lbs. weight of carded web per week from middling American cotton, we find it to consist of a back of twilled cotton, a second ply of cotton, a third ply of linen and cotton union, a fourth ply of cotton, and a face of rubber. This is the base of the cylinder and doffer clothing. Taking the foundation for the tops, the cotton-wool-cotton combination is adopted, a double ply of wool being used if extra strength be required and being a desirable thing to do. The thickness of the foundation, if a four ply, is a little over 0.1 inch, but this thickness is common with three ply, cotton-wool-cotton, the wool fabric being made stout in order to give strength.

Coming now to deal with the character of the wire used, we approach a point round which controversy has raged and still rages. The writer, like many others, at one time held the opinion that the so-called needle-pointed wire was not likely to give such good results as a plain top-ground wire, and Mr. DOBSON, in the paper communicated to this Association some years ago, took strong ground against it. To-day, in the fine mills of the Bolton district, plain round wire, top-ground only, finds wide acceptance, so that there must be some reason for the preference. At the risk of going over ground familiar to all spinners, it will aid if it is made clear what is meant by the terminology employed. By "top-ground" wire is meant that the teeth are only ground on their points transversely of their axis; by "needle-pointed" wire is meant that the upper ends of the teeth near their points are ground a little on their sides, "side ground" being synonomous with this expression; and by "plough ground" wire is meant that the teeth are ground by emery discs following a plough guide which passes between the various rows

of teeth, the discs grinding the teeth nearly to the bend. In the first of these there is no reduction of the thickness of the wire at any point; in the second, the reduction is slight, and only at the point; while in the third it is considerable, nearly half the original size, and extends for some distance down.

This is not the only difference which exists. The question of whether the wire should be used as it is produced, or whether it should be hardened and tempered, is another matter upon which controversy has raged. In the one case iron or mild steel wire is used, and is not subsequently treated; in the other, the wire used is subjected to a continuous hardening and tempering process, which gives it an additional resilience, which it is contended is of high value. It ought to be noticed at this point that the systems of hardening and tempering wire have been enormously improved in the past few years, and that conjointly with improvements in the manufacture of the steel, by which greater uniformity of structure is obtained, it is now possible to produce wire even in temper and free from scale. In this respect the improvement is marked.

Still another point of dissimilarity remains to be noted. The shape of the wire used varies somewhat. At one time round wire only was used, but at the present time there are three principal sections in use—round, triangular, and oval. Round wire is used alike for top, side, and plough ground wire, and in the latter case the tooth is made into an oblong section in the ground part. Angular wire has never come much into favor, but the oval wire has been used to a large extent, and there is something to be said for its employment. These forms are shown in Fig. 1, in which the area of the top of the teeth is

FIG. 1.

shown by the black portion in the plough, top, and needle

pointed wire, the circles indicating the corresponding size of round wire.

Having thus noted the differences existing, it is now possible to discuss intelligently the various points. As plough grinding and hardened and tempered wire often go together, wire of this character may very well be considered as a single entity. In the writer's opinion, the whole controversy with regard to this class of wire must be discussed in view of the work which is expected of it. It is idle to use the same canon of judgment in the case of a machine producing 350 lbs. of clean Egyptian in fifty-six hours, and of one producing 900 lbs. of American, which is less uniform in staple and not so clean, in the same time. The mere statement of the case shows at once the absurdity of of any such proposition. Suppose that a carding machine is clothed with round top ground mild wire, with an area at the point about 35 per cent. greater than plough ground, and it was necessary to get the same weight through each, is it not obvious that a set of conditions would arise which would tend towards failure; for, if it be true, as Mr. DOBSON contends, that the carding power of any tooth turns upon the holding power of the point, which depends on the number of serrations formed on the latter, then it is doubtful whether a tooth having this excess of holding capacity would part with the cotton quickly enough to get through the work. In the writer's judgment it is more than probable that, save for the existence of hardened and tempered plough ground teeth, the weight, which it is possible to get at the present day through carding engines, would be quite out of the question. It is not possible, here and now, to discuss the question of the quality of the yarn produced; and it is only necessary to say that no convincing evidence is forthcoming that, all other things being equal, there has been any loss of strength from the use of wire of this kind. The writer is one of those who believe that the less mauling cotton receives in the process of carding the better for it, provided always the cleansing is done well, and it appears to be well established that single

carding properly done gives a result equal to double carding. This is by the way, and should not lead us away from the point at issue.

Whatever the molecular changes may be in steel which has been hardened and tempered, it is at least certain that they do not decrease, but increase, the resilience of the wire, and it may fairly be said that it is borne out by common experience in many other cases. The main spring of a watch, for instance, is subject to an enormous number of opening and closing actions before it fails, but it is impossible to conceive of a mild steel coil being subjected to the same action without receiving a permanent set. If the action of a card tooth be considered, it will at once be seen, that it must in the course of its life be subjected to a large number of oscillations on its fulcrum, and, in resistance to permanent set, hardening and tempering must play an important part. Even top ground wire is better for being tempered, and recent experience has fully established the truth of this contention. The knowledge gained in the past few years has considerably modified the conclusions drawn, and, whereas, at first the old-fashioned methods of manipulation were thought to be suitable, and would yield equally good results in the new circumstances, it is now known that the latter require special consideration and allowance. This is the explanation of many contradictory opinions which have been expressed, but it may be taken that, whatever the character of the grinding, the tempering of the wire, if not absolutely necessary, is preferable.

Coming now to deal with side grinding, it may at once be said that what passes by this name, or "needle pointing," appears to the writer to be worse than useless. All the specimens of this form which have been examined show the grinding to be so ineffectively performed that there is little gain in doing it. It does not materially reduce the size of the wire at the point. All that it appears to do is to slightly roughen the side of the wire, the grinding being of a most perfunctory character. In addition to this there is considerable danger of the teeth being disturbed.

It certainly appears to the writer that the object sought can be better attained by the employment of a special section of wire, such as the double convex, which always presents to the cotton a comparatively sharp face, while at the same time having a shape well calculated to resist flexure.

Plough grinding stands upon a different basis. Here there is a very material reduction in the size of the wire, the sides being ground away until the width is about 55 per cent. only of the diameter of the wire. Two things follow upon this. The area of the point of the tooth is considerably reduced, and the space between the adjacent teeth is also much increased. If what has been said about the retention of the waste and neps be remembered, it will be seen that the latter element is by no means unimportant. It is necessary with cotton that is at all dirty, and which contains much nep and short fibre, that there shall be ample stowage for it until it is removed by stripping. This is very essential, and, by the enlargement of the space between the teeth, this function of card clothing is materially aided. It is urged in opposition to this view that the reduction of the area of the point of the tooth diminished its carding power by reason of the lessened number of striations. This appears at first sight an almost unanswerable objection, but its force is much weakened by the fact that what the precise action of the tooth is no one definitely knows. Even if it be assumed to be true, is it not met by the fact that the number of teeth available is in excess of the fibres to be treated, and that there is sufficient hold in each tooth to card effectively the fibre which is attached to it? Unless it be assumed that the fibres are carried round several times prior to removal, it appears to the writer to be certain that the size and character of the point will always be sufficient to carry average cotton from the licker-in to the doffer, and to subject it to proper treatment in the meantime. After all, an appeal to experience is better than much theorising, and it remains to be shown that, all conditions being alike, the web produced from American cotton by a plough-ground tooth is to-day

inferior to that made by any other form. In saying this it is not intended to declare that with different cotton the top-ground tooth is not the better. For American cotton at least, quantity and quality of product being alike considered, the hardened and tempered plough-ground tooth stands in the first rank. For Egyptian cotton, where quantity of product is of less importance than quality, and where a finer, more uniform, and cleaner staple is handled, the retention of the cotton, so as to comb it thoroughly, is more important, and here top-ground wire gives excellent results. In this case, however, the quantity of strippings is not so great, and generally a finer setting is permissible.

Nothing has yet been said as to the question of re-grinding the points of the wires, which it was at one time thought would be the chief recommendation of hardened and tempered wire. In this respect it has been found that although the excessively long periods allowed between grinding have been abandoned, the period has been lengthened, and, not only so, but that the amount of grinding each time required is much lessened. This has a doubly beneficial effect. First, the shortening of the wire is more slowly effected and its life extended; and, second, the wire is not subjected to the same number of bendings by the friction and pressure of the grinding rollers. Both these are matters of importance, and have a considerable influence upon the life of the clothing. Light and comparatively infrequent grinding are characteristics of well kept hardened and tempered wire clothing, and of their importance few can doubt.

The points, which have been numbered 3, 4 and 5, respectively, are so closely connected that it is necessary to consider them together. They are (3) the angle at which the wire leaves the foundation; (4) the angle of forward inclination at the bend; and (5) the relative height of the bend and point.

The angle at which the wire leaves the foundation is one of the most important matters in connection with the subject. It forms what may be called the base upon which all the superstructure rests. An attempt will be made to put this matter

clearly, and to show its full importance. A card tooth must be looked upon as a lever having its fulcrum at the point where it leaves its supporting matrix and receiving pressure upon its free end. It is obvious that the more nearly the tooth from the point to the fulcrum approaches a straight line the more regular will be its oscillations. Suppose, for instance, that the tooth is straight, as shown in Fig. 2, and that it is bent back to the posi-

FIG. 2.

tion shown by the dotted lines; when the pressure is applied, it will practically radiate about its centre, and will not in doing so affect the relative position of the point to the rest of the tooth. It is well known that for many reasons it is desirable to give the upper part of the tooth such an inclination that it will readily grip the cotton fibres and hold them. Except some such inclination was given, it would not be possible to give the tooth a point which would effect this object. This is illustrated in Fig. 3, in which the tooth is shown, first, with its upper part

FIG. 3.

vertical; and, second, at a proper angle. It is at once seen that the tooth, when vertical, is ground substantially at right angles to its axis, and thus, when rotating in its path with the cylinder, presents practically no point to the cotton delivered from the

licker-in. On the other hand, the angularly set tooth, also ground transversely by the roller, receives such a shape at the point as causes it to present a sharp nose to the fibre. It has, in fact, been subjected to a treatment, which in the preparation of cutting tools, is called "backing-off."

The bearing of this upon the angle at which the tooth is set in the foundation does not at first appear to be clear, but by the aid of a few sketches can be made so. It should be premised that nothing has yet been said upon the angle of the bend of the tooth, and at present it will be arbitrarily assumed that the point of the tooth is always in one position, the accuracy or otherwise of which will be discussed later. Let, then, in Fig. 4,

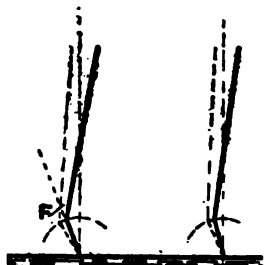


FIG. 4.

A be a tooth the angle of which, as it leaves the foundation, is 70 degrees, while B is a tooth the angle of which is 76 degrees, the formation being otherwise the same. If it now be assumed that each tooth is pushed back at the point 5 degrees, the position of the lower portion is indicated by the dotted lines, and a measurement shows that the angle of A has been reduced from 70 degrees to 60 degrees, while the angle of B only shows a reduction of from 76 degrees to 70 degrees. In other words, there has been a greater movement of A than of B, and necessarily a greater inclination for the tooth to lie back instead of standing up firmly to its work. If this excess of oscillation be accompanied by any other defect in construction, it is very likely to set up a permanent "set back" in the tooth as it leaves

the foundation. What is wanted is to get the maximum of movement of the point with a minimum of movement at the root of the tooth, and this is best accomplished if the tooth stands up well to its work. In some actual examples of clothing, as shown in sketch Fig. 5, the tooth, having been set in the

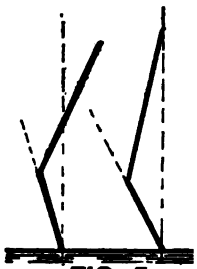


FIG. 5.

foundation at too acute an angle, acquired a permanent "set back" of nearly 10 degrees, with the result that the whole of the effect of the forward inclination of the tooth was entirely lost, because the laying back of the portion below the bend carried with it the upper part of the tooth, and made it assume nearly a vertical position. If a comparison be made with the straight tooth in Fig. 2, it will be seen that the further the departure from a right angle where the tooth leaves the base, the greater the inclination for it to lie back in work. The latter condition is a dangerous one, for, while it may be true that there is strength enough for the tooth to recover itself, it is equally true that the stress on the foundation fabric is greater, and the latter is more liable to yield.

There is another point which is affected by the acuteness of the foundation angle, namely, the forward inclination of the bend. Again, using as an example the tooth shown at A and B in Fig. 4, it will seem that, in order that the point may terminate the same number of degrees in front of the vertical, the angle of the bend marked F is in A 32 degrees, while in B it is only 21 degrees. In common parlance tooth A is much keener than B, and in conjunction with the greater forward inclination

is the fact that the point of the tooth will be ground much further back, making what is known as a long point. The inevitable tendency of this is to make the tooth hold and carry the cotton more firmly, and even the short fibres will be more difficult to remove.

Coming now to the question of grinding, when a certain downward pressure is put on the tooth in a direction radial to the centre of the cylinder, the line of thrust is such that it tends to force the tooth inward, although at the same time the rotation of the roller gives it a forward oscillation on its fulcrum. If between the foundation and the bend the tooth lies back too far, and if the forward inclination of the bend is too great, the effect of any pressure exercised in a radial line is to cause the tooth to collapse. In other words, the more nearly the line of the tooth approaches the line of thrust the greater the resisting power to breaking back This is easily shown if the tooth shown in Fig. 6 be considered, this being an exaggerated view

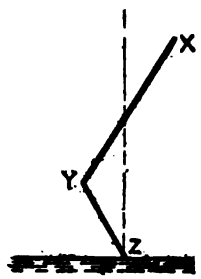


FIG. 6.

for the purpose of illustration. A weight applied at the point X would tend to collapse the tooth alike at Y and Z, while a pressure put on it at X in the direction of X Y, would simply render more acute the angle formed at Z with the foundation.

There is yet another point in which this matter is important. As has been said, the strips, fly, and the like become embedded in the teeth on the clothing, and are periodically cleaned out by a stripping brush generally made of light wire or bristles. The strength of this wire is not great, and it has to hook into the

strips and lift them out. If the base angle of the wire be too acute, and especially if that acuteness be accompanied with a too great height of bend, it is difficult for the stripping brush to lift the strips out of the clothing. The result is that the space below the bend becomes filled up or "felted," and the tooth has not the same freedom of movement that it ought to have. This is a fault which is not often found, but it is one of the effects arising from too acute an angle at the base.

For all these reasons, therefore, it is desirable that the angle of the tooth with the foundation should never be too acute, and it may be taken as a general rule that a minimum of 75 degrees should be adhered to. In many cases the angle is greater, but it cannot be much less without endangering the stability of the clothing. This point is one which requires treating broadly, and it is permissible to make variations from it provided that the full effect of them be considered, and the necessary precautions taken.

We have seen, for instance, how the forward inclination of the bend is affected by the base angle; but there is another factor which is also important, namely, the height of the bend from the foundation. This, if excessive, aggravates alike the tendency toward breaking back and the forward angularity of the tooth. Thus, in Fig. 7, two teeth are sketched, each having the same

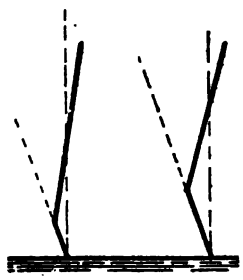


FIG. 7.

base angle, and each having its point terminating the same distance in front of the vertical. In one case the distance from the foundation to the bend is half the distance of that of the second,

and the effect is that the forward inclination of the upper part of the tooth in the first is 29 degrees, and in the other 34 degrees. Thus the base angle, plus the high bend, results in a bend angle much greater than is found when the bend is lower. If a tooth so constructed be compared with one in which the base angle is less acute and the bend a reasonable height, it will be seen how far-reaching in its effects is this combination. In cotton cards, at least, it is inadvisable to have the bend too high, because only a moderate forward inclination is desirable, and the effect of a high bend is to affect its angle. The height of the bend depends upon how far from the crown of the tooth the latter is bent. In worsted, woollen, and cotton waste cards the bend is made about half way betweed crown and point; but in cards intended for carding cotton by flats a ratio of 3 to 4 represents approximately the length of the tooth from crown to bend and from bend to point. This ratio varies somewhat, but in the generality of cases is never greater than 4 to 5.

Coming now to deal with the last-named point, it is not too much to say that this is the vital feature which, more than any other single one, affects the proper working of card clothing. In order to make this matter clear, recourse must be had to the sketch given in Fig. 8. In this the tooth is assumed always to

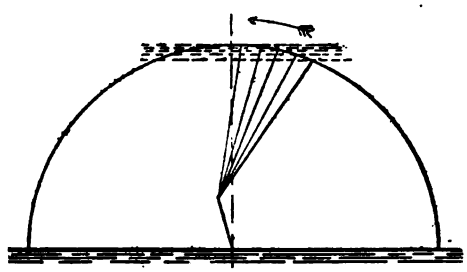


FIG. 8.

leave the foundation at an angle of 75 degrees, but to be bent forward so that its point terminates 3, 10, 15, 20, and 25 degrees respectively to the right of the vertical line. If, now, lines be drawn parallel with the base through these points respectively,

it will be noticed that they pass below the crown of the arc of the circle. If, therefore, the respective lines be looked upon as the normal plane in which each tooth works, it is at once apparent that if the tooth be caused to radiate in the direction of the arrow about the fulcrum, its points will rise above its normal plane, and will, if the movement be continued far enough, come in contact with any surface above it. In view of the close settings which are now made between cylinders and doffers, and cylinders and flats, it is evident that any shape of tooth which gives this result is faulty, and will not do good work. In any case it is desirable for the upward part of a card tooth to be only moderately bent forward, and it should not be in front of the vertical line more than 3 to 5 degrees, in which case, as the illustration shows, the rise of the point is trivial. This is the most important matter, taken singly, in the whole construction of card clothing, especially for machines in which flats are used. It hardly needs any demonstration, the diagram given being self-explanatory. It may possibly be suggested that a coincidence of the point and the vertical line would be the best condition, but that is not so. A slight forward inclination is necessary, so that the point may pick up and retain the fibres, a process which is aided by the backing-off in grinding consequent upon the forward inclination, as previously noted.

With reference to the thickness of the wire used this is a matter in which there is a good deal of variety. The determining condition here is purely the work to be done. Fine carding and light weights enable a finer wire to be used than is permissible with heavy carding and weights. The measurement of card wire is made by a gauge, the grading of which is determined by the makers. The counts of wire generally employed in carding machines for American cotton range from 100's to 130's, and the gauge of wire employed varies from Nos. 31 to 34 or from .012 of an inch to .0096 of an inch a size being in the most commonly used gauges .0008 inch. For 100's counts the wire used generally with heavy weights of production is No.

31, for 110's No. 32, for 120's No. 33, and for 130's No. 34. If the cards are intended to deal with small productions and fine carding, such as Egyptian, finer counts and finer wire can be used, these being respectively 120's counts and 32 1-2 or 34 wire for doffer and tops. At the same time even for Egyptian cotton the stouter wire is often selected. The difference in the thickness of the wire from gauge to gauge is, it is true, slight, but relatively it is great, being about 5 per cent. The general rule may be stated that for American cotton the cylinders should be clothed with fillets 110's counts and 32's wire and the doffers and tops 120's counts and 33's wire. For Egyptian cotton finer counts and wire are permissible as stated.

We now come to deal with a question which more than any other has puzzled spinners; that is, how to ascertain the counts of card clothing. The matter is rendered more difficult owing to the variation in the method of setting which has taken place during the past few years. When the system of grading now prevalent was adopted it was based upon the fact that the teeth were set in sheets 4 inches wide, and ten "crowns" or pairs to each inch of length. This was, of course, the procedure when the teeth were set by hand and were "plain" set as it is called. The clothing is now made in strips or "fillets" 2 inches wide for the cylinder and 1 1-2 inches wide for the doffer. For the tops they are made in sheets of the full width of the flats, but are only set in bands which are the width desired. So far as the character of the setting is concerned it is practically the universal rule to set them for cylinders and doffers "ribbed," as shown in Fig. 9. The "twilled" setting as it is called, which is illustrated in Fig. 10, is mostly used for tops. If a cylinder or doffer fillet be examined at the back, the teeth are seen to be set in rows or ribs, there being a clear space between each rib, which consists of successive groups of three crowns set so as to overlap one another. On turning the fillet over, however, no such break in the spacing of the points is seen, these, if properly set, maintaining an even space in all directions. Under the old system

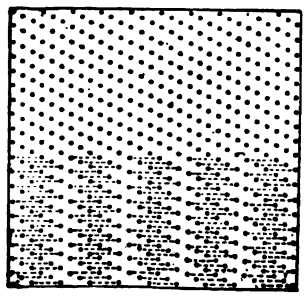


FIG. 9.

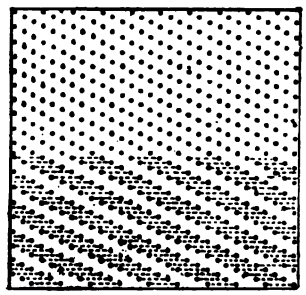


FIG. 10.

it was easy enough to calculate the counts of the clothing. The standard 4 inches wide, with a definite number of crowns, gave the counts. Thus, 100 crowns in a width of 4 inches was 100's counts, and the number of crowns per square inch $\frac{100 \times 10}{4} = 250$. In like manner 110's had 275 crowns per square inch, and 120's 300. If this be examined it will be seen that there are, on this computation, 2 1-2 times the number of crowns, or—as each crown implies two teeth—5 times the number of teeth per square inch as the counts of the clothing. This gives us the means of calculating the counts, however widely the traditional setting may be departed from. Thus, to select an example from actual practice, take a 2 inch cylinder fillet, with eight ribs in the 2 inch wide, and 23 crowns to the inch longitudinally. There are thus 24 crowns in the width—there being three in each rib—

or 48 in the full width of 4 inches. It should be noted before proceeding further that the crowns per inch of length only refer to those in a straight line along the edge of a rib, the triple combination having been previously taken into account. Then we have 48 × 23 = 1,104 crowns in the four square inches, or 276 per square inch. Dividing this by 2.5 we get 110's which is the actual counts of the clothing. If the number of teeth be taken instead of the crowns the result is the same. In this case the calculation is $\frac{96 \times 23}{4 \times 5} = 110$. To make the point quite clear, take a fillet with seven ribs or 21 crowns in 2 inches but 26 crowns per inch length, then the calculation is as follows: $\frac{42 \times 26}{4 \times 2.5} = 109.2$ counts. It will be seen that in this case the counts are not quite up to the mark, but the effect of getting 26 crowns in each inch of length, instead of 23, is to crowd the teeth together, a procedure which is inadvisable, and necessitates a finer wire. If a doffer fillet be taken with six ribs in a width of 1 1-2 inches, and 25 crowns per inch long, we get the calculation $\frac{48 \times 25}{10} = 120$'s, which is the intended counts. These examples serve to show the method of calculation. It is well to stick to the width of 4 inches, because of the fact that it is sometimes necessary to break a rib if only 1 inch be taken. Thus, in the seven-ribbed cylinder fillet the number of crowns is 10 1-2 only, but from this the calculation could be easily made. Thus $\frac{10.5 \times 26}{2.5} = 109.2$ exactly, the result previously attained. The rule may be formulated thus: Number of crowns per inch wide x number of crowns per inch long, 2.5.

Before closing it may be well to say a few words on the question of grinding cards. It is generally conceded that to wait until the points of the teeth are dull and then grind them on the top is a mistake, and it is infinitely better to grind lightly for a few minutes often than to grind heavily for a longer time and at greater intervals. Hardened and tempered wire has been accompanied with an improved grinding material, and although it is true that the striations formed on the crown of the tooth are

not so deep as those produced in mild wire they are more permanent. Under ordinary conditions of work once in six weeks is a good time to grind, and the carding power of the machine will not suffer much by this procedure. Generally opinion is gradually coming to the conclusion that during these periodical grindings it is better to run the cylinder in the reverse direction to that in which it works, but at its working speed. After clothing, the use of slow grinding for the early stage is alike permissible and advisable, but the finishing should be done with a light pressure and at working speed. For grinding the cylinders and doffers the Horsfall traversing roller covered with Dronsfield's special emery fillet gives good results, and for revolving flats the dead roller is preferable. The thing to avoid is the formation of barbs or hooks, and these are sometimes so easily produced that great care should be taken to avoid them.

The writer is especially desirous that what has been said should not be taken too literally. In some particulars with the best made clothing it is impossible to avoid variations which arise in working, and are the result of the nature of the material employed. Thus, hardened and tempered wire does not take a permanent set so readily as mild wire, and although due allowance is made for this, the speed at which the operation is conducted causes some variation in the setting. There are, therefore, reasonable allowances always to be made, but it will be found that these are not more than may be expected from the exigencies of the manufacture. A good sample of card clothing will have a foundation constructed in such a manner that it gives a firm sustainment to the tooth, while being sufficiently flexible, which, when laid tightly upon the cylinder, will not stretch in work, and which has in it endurance sufficient to enable it to withstand the high temperature to which it is often subjected. The wire used should be sound, homogeneous, and free from defects on the surface. Whether drawn, or hardened and tempered, it should have a surface free from scale, and if side ground should have as many of its asperities removed as possible. It

should be capable of receiving and maintaining a sharp point. The angle at which the tooth is held in the foundation should not be too acute, nor the bend too high, and the forward inclination from the bend must not be too great. Given these points and a sufficiently strong wire, a clothing is the result which is capable of rendering good service for many years with reasonable care. The tooth shown in Fig. 11 may be taken as the

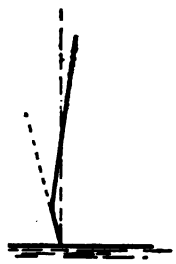


FIG. 11.

type of one which works satisfactorily.

Another point may be mentioned. It is sometimes the practice when a tooth is too keenly set, as in the left hand view in Fig. 5, to subject the clothing when fixed in the cylinder to a process known as "facing up," which is effected by holding a special rubber in front of the teeth during the rotation of the cylinder and exercising a light pressure on them. This is a practice which, if the teeth are properly set, is entirely unnecessary, and when it is carried out, results in the forcing back of the teeth at the base, as shown in the right hand view of Fig. 5. Although the point of the tooth may be brought into the right position relatively to the vertical, it is accompanied by a material and serious alteration of the base angle, which is, as shown, a most important matter.

One other thing may be dwelt with as a final point. Of the importance of properly securing the clothing to its working surfaces every one is convinced. The procedure is well known so far as the cylinders and doffers are concerned, but it may be well to put in a plea for the employment of one of the numerous

clips which grip the clothing and flat, thus firmly holding them together. There are several of these now in use, and if properly applied they hold the top firmly on the surface of the flat, and at the same time protect the foundations from damage by the stripping brush. In addition to this, the flat is not weakened by piercing it near the edge, but, on the contrary, is stiffened by the application of the clips. In view of the deflection of the flats when in their working position, every aid towards maintaining their rigidity is important, and the use of this form of fastener is to be welcomed as a means of effecting a firm hold of the top and at the same time helping to make the flat less liable to deflect.

The object of the foregoing remarks has been to put into an intelligible shape the principles which underlie the construction of card clothing. There is no attempt to give such a series of measurements as were contained in Mr. DOBSON'S paper. These, in themselves, are valuable, but beyond noting the fact that differences exist, their effect is not dealt with. What the writer has tried to do is to show the effect of any particular variation, and to formulate the principles underlying the practice. Only in this way is it possible to appreciate the results which flow from small causes. The endeavor has been to put clearly and practically the points affecting the construction and working of card clothing, in order that an intelligent interest may be taken in an important adjunct of cotton spinning.

The PRESIDENT. The next topical question is No. 32, "What is the best method of ventilating rooms: *a*, carding; *b*, spinning; *c*, weaving?"

Mr. A. F. KNIGHT. I would say, Mr. President, that I suggested the topic under head of No. 32. I have no opinion of my own that is worth anything, but I wish that it might be discussed before the Association.

Mr. D. M. THOMPSON. Mr. President, I believe that some of the systems which have been presented are worthy of consideration.

The vapor steam systems so long in general use, operate well during the period of cold weather, but it is impossible to maintain uniform conditions during the season when windows are allowed to be open for ventilation. I therefore believe it is essential to have a system which shall maintain a practically uniform condition of humidity at all times, and, as nearly as possible, a uniform temperature.

About eight years ago I had a case where we were changing one of our mills from our "Fruits" to "Fruit Cambrics." There were 300 looms upon the third floor; we had vapor, steam and the "Garland Atomizer." After starting upon the fine goods, I was obliged to increase the number of vapor stations 50 per cent., to secure an even distribution with minimum steam. The results were fairly satisfactory until the hot weather of July came, when the temperature became almost unbearable, and was only measurably relieved when the windows were freely opened top and bottom. In this situation the necessary conditions for good weaving were destroyed.

I therefore hastily devised that which may be termed a blower system. In the basement of the mill I built a chamber about 12 feet wide and 80 feet in length, enclosed with light brick walls; in view of the experiment I put in wood partitions 4 feet apart, allowing a space of 2 feet at the bottom of one and a like space at the top of the next, and so alternating throughout the

series. I then put in a pipe extending longitudinally through the chamber with branches on each side thereof, extending the width of the apartment and located in the centre of the 4-foot spaces. These branch pipes were perforated and water was discharged continuously under a pressure of about 10 pounds per square inch. One side of the chamber was connected by a pipe with the outer atmosphere — in this instance with a race-way leading from the wheels. At the other end of the enclosure was set a large exhaust fan, which drew the air through the numerous compartments, and thence forced by the blower into the weaving room through an 18-inch diameter galvanized pipe, thence to the centre of said room where it branched right and left, gradually reducing in size as it extended to cover the looms. At intervals of 32 feet, 7-inch diameter branch openings were introduced on each side, provided with dampers.

Immediately upon starting this system every vestige of the former troubles disappeared, we discontinued entirely the use of vapor steam, there was no further need of the "Atomizer." This occurred about the 10th of August. We closed all of the windows in this room except four (two on each side); these were at middle stations central to the two sections of looms, and were dropped from the top only 6 inches.

The temperature of the room was found to be from 8 to 10 degrees lower than formerly, when all windows were freely opened, while a uniform condition of humidity was maintained and regulated at any point desired. The improvement was one of the most marked in its results, both as to the comfort of operatives, and in the amount and value of the product from the looms, that I have ever witnessed.

Another incident worthy of mention is the fact that we had previously had much trouble with electricity in the carding department of this mill, which was located on the floor below these looms. The looms were belted from below so that the air forced into the weave shop was distributed through the belt openings in the floor, and dissipated entirely the previous trouble.

The amount of air delivered to this weaving room, 50 feet by 300 feet by 15 feet, was sufficient to change the entire atmosphere once in 30 minutes.

I have introduced this system into several of the other mills, then under my management, with satisfactory results, and varying only according to the physical conditions existing which, in some cases, would not admit the full treatment given in the case above cited. I have used some of the latter systems and regard them with favor, but none in my experience so fully met the conditions which I regard as ideal and essential as the blower system.

Mr. C. J. H. WOODBURY. Mr. President, at this present time it goes without saying that the best method of ventilating a mill is what is known as forcing air into the various rooms, but it is yet an open question as to the best method of forcing that air, and also that a system of ventilation must also be a system of heating. About a year ago I was a referee on a question of a contract of ventilating a very large building by the system of forcing the air by means of a blower through a collection of steam heating pipes. I asked the persons at the interview questions in regard to their systems. Each of them could only dogmatically answer that their own was better than the other kinds. The point of difference between the various bidders was almost entirely upon the type of blowers, whether it be the fan or centrifugal, or the disc or propellor type. The persons interested would only answer dogmatically that their blower was better than the other kind. Remembering hearing a remark ascribed to Judge JERRY BLACK, that it never hurt a good case to be tried before a judge who knew something about it, I sought in various directions to obtain information relative to the efficiency of blowers under the known conditions of volume of air moved and the pressure to be produced, and I must confess that my efforts resulted in failure so far as learning the desired facts was concerned.

When the steam pipes are in one place, there is a less amount

of repairs, all the piping is under the control of one person, and the efficiency of the steam heating system per square foot of radiating surface is many times as great as when the pipes are distributed over the building.

I believe that there is something to be said, in some instances, in favor of the method of direct heating by steam pipes, and that comes to the consideration of the two methods of arranging the steam pipes. On one hand, when the steam pipes are arranged around the room in the usual way near the floor, and the other when they are hung from the ceiling, about three feet from the wall and not less than two feet from the ceiling. From direct experiments it is found mills are heated with about 25 per cent. radiating surface by the overhead pipes. The original method of heating mills by steam used large four to six inch cast iron pipes hung from the ceiling, though the lower part of the room would be naturally the place where the heat is desired. When the pipes are hung from the ceiling they can effectually radiate heat in all directions, and when they are placed at the side of the room, near the floor, they can heat outward only, and this circulation is frequently impeded by branches. So that the question seems to resolve itself, that the best method for a new mill is having properly arranged pilasters containing flues suitable for conveying heated air; if the building is already constructed, the next best method would be by hanging the pipes from the ceiling.

But the next question arises, to what height of room are overhead pipes directly applicable? With the ordinary mill of thirteen feet or more in the clear, there is no difficulty to the help from the heating of the steam pipes; but in some of the older mills, where they are ten feet or less in height, there is a great deal of difficulty from heat radiating directly upon the heads of the help, and therefore the question resolves itself into the wants of the mill, which must be solved for every condition.

Mr. A. F. KNIGHT. Mr. WOODBURY has said that the best method is by forcing air into this building. I will say that my

personal opinion is the same as Mr. WOODBURY'S, but we know very well that there are lots of gentlemen who think that it is better to suck the air out of the room.

The PRESIDENT. The next question is No. 33, "What is the best method of sizing cotton warps?"

On motion, duly seconded, it was voted that this question be laid upon the table.

The PRESIDENT. The next question is No. 34, "What is the best method of lubricating shafting overhead, in weaving rooms, to prevent oil stains on cloth?"

Mr. A. F. KNIGHT. That is a topic which I also presented to the Association. I don't know how to overcome it, and for that reason I presented it to my friend Mr. KENT.

Mr. JOHN TEMPEST MEATS. To open the discussion I may cite an experiment made since last meeting. Having occasion, during the fall, to put up a line of shafting to run 200 revolutions per minute, with about a dozen bearings, 8 feet apart, I made use of a self-lubricating bearing which had given good results on mule countershafts; and, as a test of cleanliness, had suspended, under each bearing, a piece of drawing paper, so that no oil could escape without showing on the paper. Two days ago I found ten of the twelve papers perfectly free from oil, after three or four months running without any attention whatever.

Mr. W. J. KENT. I will send him an order for several to prevent oil stains.

Mr. R. W. EATON. The best method of lubricating shafting is to have a bearing where you do not have to use any oil. I should be very sorry to see this question go without discussion. Let my friend get a few of these bearings, and he will find that no oil will drop. As to the thirty-fifth question, Mr. HOLMES is working on the subject of drawing rolls, and I think he will be

able to show you a bearing before a great while where you will have no need to oil the rolls at all.

Mr. A. F. KNIGHT. Mr. President, since the matter of graphite has been brought up, we have had trouble with loose pulleys, and having in mind Mr. EATON'S paper, ordered some bushings for pulleys, and a number of them have been put in. We have had trouble with only one. I don't know what happened to that. As it was explained to me, it all went into a powder, and much to my regret the powder wasn't saved so that I could see what condition it was in.

Mr. R. W. EATON. Mr. President, I think I stated at the last meeting that Mr. HOLMES says there is a difference between a loose pulley, and having a shaft run in the bearing.

Mr. HENRY T. WHITIN. Mr. President, how about the power taken to drive it? Does it take more power to drive shaft with graphite bearing thon any other? I don't know, I simply ask for information.

Mr. STEPHEN MINOT PITMAN. Mr. President, graphite bearings have never worked well on loose pulleys. They work in a box for line shafting all right. I have had considerable experience with graphite bearings, having been general manager of the Holmes Fibre-Graphite Manufacturing Company, of which company I am still vice-president, Mr. HOLMES being the president, and I would say in regard to the comparison of the amount of power of graphite and oil bearings that the tests show a little in favor of the graphite when compared with a well cared for oiled bearing, but in practice oiled bearings are never kept in the best condition. Then we have tried it where the power was furnished through an electric motor, so that the power could be measured very carefully, and we found that there was not much difference in the power required; sometimes they took a little less and sometimes a little more than the oil bearings.

Mr. A. F. KNIGHT. Mr. President, I will say that in ordering these bearings, I explained to the Holmes Company what they

were to be used for. On loose pulleys for countershafts when they are running something like 500 revolutions per minute. In replying to my letter they stated that they had a loose pulley running in their plant on one of these bushings, and that they glued the bushing on the shaft, and recommended me to do the same thing. This did not seem to me to be the proper thing to do. The bushings were made three-fourths of an inch thick on each side. They knew that we were going to put them on pulleys, and arranged it for them to stick out a little on each end. One of them, as it was explained to me, went into a powder.

Mr. JOHN H. RUSSELL. I would ask whether you put any oil in?

Mr. A. F. KNIGHT. Just put a little oil in.

Mr. STEPHEN MINOT PITMAN. It will not do to put any oil on a graphite bearing.

Mr. A. F. KNIGHT. You are talking about continuous lubrication, are you?

Mr. STEPHEN MINOT PITMAN. You cannot put any oil on; if you put on a little once or twice it gums up; if you put it on regularly it softens the bushing and it crumbles.

Mr. A. F. KNIGHT. I am very much surprised at this, because it was represented to me that while it wasn't necessary to use oil in the graphite bearings, that when it was used it would run with less friction than when they run alone. The wheel we proposed to run without oil as near as we could.

Mr. STEPHEN MINOT PITMAN. Graphite bearings are almost indispensable for some purposes, but they are not good for everything; for instance, they cannot be used for the bearings of railroad locomotives, the pounding and jarring breaks the bearings all up. Graphite bearings do the best either for very light work or else for very heavy shafts that run steadily and slowly without jarring; for example, in the bearings for calendars in paper mills, for which they are especially fitted, as they stand the effect of heat, steam, and even acids.

Mr. A. T. ATHERTON. Mr. President, I had a talk with Mr. HOLMES. He told me that moistures of any kind, either water or oil, had no effect.

Mr. D. M. THOMPSON. Mr. President, I would say that Mr. HOLMES called upon me a few weeks since and during the conference I had the pleasure of talking to him upon the subject of his graphite bearings. I first became interested in this question through its presentation by Mr. R. W. EATON at our last meeting. I was strongly confirmed in this feeling by the representations made to me by Mr. P. H. HOLMES; I confess that I am disappointed after listening to the statement of Mr. PITMAN'S experience, and Mr. KNIGHT'S test of a few of the bearings. It is possible, however, that they apply to some of the early experiences, and that subsequent improvements may have removed the trouble. I am convinced that Mr. HOLMES feels assured of its success; I recall that he made reference to Mr. GOODALE as having had a considerable experience in the use of these bearings.

Mr. STEPHEN MINOT PITMAN. The bearings that Mr. GOODALE has are among the first ones put in anywhere. They were put in some four or five years ago, and the ones made now are much more satisfactory.

Mr. D. M. THOMPSON. Mr. President, I believe the matter is of sufficient importance to justify a careful investigation; with this end in view, I have ordered several pairs of journal boxes of various sizes for the purpose of trial and experiment. I would suggest that other members, so far as possible, make a trial of them, and that we report results at our next meeting.

Mr. HENRY T. WHITIN. Mr. President, I know of a shop requiring 38 per cent. of power to drive the shafting. The gentleman I was talking with said it took a great deal of power. Still it comes to the coal supply to those who live thirty or forty miles inland. I was in hopes some one had made experiments.

Mr. WM. J. KENT. Mr. President, when I was a kid at Lonsdale, my grandfather used to tell me about a man in Woonsocket

who was considered a very smart spinner, and I heard so much about this man that I was quite anxious to see him. One day, about fifteen years afterwards, the man referred to presented himself at my office and asked to see me. The office boy came to me and announced him. From what I had heard I expected to see a man about six feet tall and weighing 200 pounds; you can imagine my surprise when I looked upon the man who presented himself — not over five feet in height. This man was WILLIAM WELCH; he is now in the audience and I would like to ask the members of this Association to give him permission to speak; he will tell us something about the question which is now before us.

Mr. WILLIAM WELCH. Mr. President, I say that the best thing I have ever seen is a piece from thick felt or flannel, thoroughly saturated with good oil. It will not, in my opinion, let any oil run out on the rolls. I never allowed my help to put an oil can spout on the rolls. I shoved a piece of sponge in from the end so that it came out at the upper end, and through that I put a wire which held it in position. I had just a drop or two of oil put on it. I never had a roll wear out while I was there, and I rarely had any trouble with rolls getting dry. The Sawyer spindles which are become almost obsolete, ran at a speed, I think, of 7,500 revolutions per minute. When we oiled these bearings, the oil went in and was carried up by the centrifugal force. When the girls went to take off the bobbin, the oil which came up on top of this bolster threw out and spatterde the bobbin each side of the bolster. A gentleman came into my room once and discovered a creamy streak in the fibre. He said, "William, what causes that?" I didn't know, and told him so. But I investigated, and found that it was this oil that flew off the bolster, and I immediately told my boss not to move the waste that gathered on the top of the bolster, as it acted as an absorbent, and that trouble immediately ceased. I will say right here, that about fifteen years after, I left that mill. The man that followed me ordered that dirt removed, and I learned that

they had to put a man on to watch the oil. I attribute it to nothing else than taking off that waste. [Applause.]

The PRESIDENT. The next question is No. 36, "What is the best number of wire and number of points, per square foot, for cylinders, doffers and flats, for the plain top card? *a*. On breaking carding? *b*. On finisher carding? *c*. On single carding? *d*. Also on the cylinders, doffers and flats of revolving flat cards?"

On motion of Mr. A. F. KNIGHT, duly seconded, it was voted that this question be laid on the table until the next meeting.

Mr. WM. J. KENT. Mr. President, I move that the next question be laid on the table.

The PRESIDENT. The next question, No. 37, Would not a device, entirely separate from the governor, applied to steam engines or other motors to stop them when five to ten per cent. above speed prevent many fly-wheel accidents? I believe a gentleman is here from out of town who desires to say something about, as he is not a member, with your permission, I think that we may call upon him.

Mr. L. W. SWEET. Mr. President, I rather regret that I am called upon to present this subject, because I am somewhat largely interested that line, and found that most all of the devices were failures. As soon as I became interested, I had to employ an expert stenographer and typewriter to answer the letters of inquiry I received. Your textile journals, magazines, trade papers, have been agitating the question for years. There have been twenty-seven fly-wheel accidents in the United States since January 1st. One occurred in Nashua a few weeks ago. I will just quote one or two lines. "In view of the many recent accidents due to the sudden increase of piston speed, and the total inability of the governor to control the same, we feel that some kind of an automatic independent stop motion is getting to be almost an absolute necessity." My experience has been that it

wants something that will do just as the engineer would do if he were there,— to stop it. I am not here to advertise it. One accident took place in Philadelphia, a 68,000 pound fly-wheel being thrown in the air. With the application of this device you have an absolute protection.

The PRESIDENT. The next question for consideration is No. 38, "What is the comparative cost of arc and incandescent lighting?"

Mr. SIDNEY B. PAINE. I received the following letter this morning from Mr. D. L. GOFF. I would say that with the inverted arc it is impossible to make a shade in the room, by putting your hand near the floor.

PAWTUCKET, R. I., Tuesday, April 23, 1895.

SIDNEY B. PAINE, ESQ.,

Dear Sir: — In answer to your inquiry regarding our experience with the inverted arc lamp, and the economy of this method of lighting by reflection, we have to say that after a year's trial we are simply delighted with the perfection of the illumination, and the saving in cost of maintenance over gas or incandescent lamps. We have had 42 inverted arcs in use during the past winter, and before next winter intend to equip our entire works. We find that the cost of installing 100 incandescent lights, or their equivalent illumination in arc lamps, is about the same, with the present low price for arc lamps. The cost of maintaining the arc lamps at the present price of carbons, and including interest, is about the same as renewals on the incandescent plant. In favor of the arc lamps, you must remember that they are always up to full candle power, while the incandescent lights begin to deteriorate from the moment they are put into service, and as they are generally allowed to burn too long, the result is, the illumination becomes very unsatisfactory. There is another serious fault with the incandescent light for mill use (that is for worsted mills, for I know nothing about its use in cotton mills), which shows itaelf in an oily scum depositing on the outside of the glass bulbs, and of the same character as we find on our window panes, which require washing every year with strong suds. This greasy deposit on the bulbs readily collects lint and particles of

dust floating in the air, and the result is, the light is very materially decreased, unless the lamps are removed from the sockets and washed, and of course they are seldom put through that treatment. We have been using incandescent lights, 20 candle power, for nearly fifteen years, and so far as cost and illumination go, we prefer gas. We have long wanted to use the arc lamp, but its intense light and deep shadow has seemed to forbid its use in posted rooms, or rooms having much shafting and belting. Now that we can light by reflection, so that there are absolutely no shadows, the arc being invisible, while a soft mellow light reflected from a white ceiling is evenly diffused, we think we have found the ideal system for mill lighting. In the form we are at present using the light, there is some criticism from insurance men about danger from sparks, but we think changes can be made to cover that point, and with this modification we believe it is the best light yet invented for mill and store purposes.

Now, when I tell a man who has not seen this method of lighting that it produces a far better illumination for much less money than lighting by incandescent lamps, or by gas, he is inclined to doubt my statement, and probably says to himself that I am mistaken, and that it is impossible to produce more illumination for less money, when we twice reflect the light, once from a reflector and again from the ceiling. I admit that this line of argument is plausible, and it may be that an arc light behind a plain glass globe loses a certain per cent. of efficiency, behind a ground glass globe a certain per cent. more, and it may be that with a reflector 50 to 75 per cent. of the light is theoretically lost. All this may be true, I don't know, but what I do know is, that you can see more and better by a reflected light than by an open light. The human eye is the final test, and not mathematical instruments, and one needs only to see the reflected lighting to appreciate it and be convinced. My theory is, that the open light causes the pupil of the eye to contract, while the hidden light allows the pupil to expand, thus enabling the eye to see more, with the same or less quantity of actual light.

But enough regarding the character and quality of inverted arc lighting. What you and many others want to know is, whether it really costs less than other forms of lighting. This question we are able to answer in the affirmative, and I submit the following comparative tests made in the month of January last. The braiding room, in which the first test was made, is 136 feet long, 66 feet wide, and 12 feet high.

There are two rows of posts, a main shaft running about half the length of the room, and three short counter-shafts about the centre of the room. The machinery consists of 420 braiding machines, distributed in 14 rows of 30 machines each. The room was formerly lighted by 84 gas jets. It is now better lighted by 8 inverted arc lamps, placed in two rows, each row 17 feet from the side walls. The lamps are run two in series on the continuous current system, 110 volts, each pair of lamps taking 9 amperes of current. The test (2½ hours each evening) resulted as follows:

The first evening 84 gas jets consumed 1,890 ft. at $1.50 per M.,	$2.83
The next evening 8 arcs consumed 9,900 watts at 15 cts. per M.,	1.48
Difference,	$1.35

or a saving of 47 per cent.

A similar test was made in our worsted spinning room, which is of the same dimensions, and contains 24 English spinning frames, 12 twisters, and 3 spooling machines. This room was considered a difficult one to light, as the frames are high, and the alleys narrow. The room was formerly lighted by 82 gas jets distributed so as to give the light where most needed. It is now better lighted by 10 inverted arcs. The result of this test was as follows:

The first evening 82 gas jets consumed 1,845 ft. at $1.50 per M.,	$2.79
The next evening 10 arcs consumed 12,373 watts at 15 cts. per M.,	1.86
Difference,	$ .93

or a saving of 33⅓ per cent.

In these tests the price for gas is the price we pay to the Pawtucket Gas Company. The price for electricity allows us a good profit for the making of it with our own plant. It is one-tenth of the price for gas per 1,000 feet, and this, Mr. Haskins of your meter department says, is a fair basis on which to fix a price for selling electricity for lighting.

In closing this long letter, allow me to say that I shall be pleased at any time to show you and your friends the arc lamps, and furnish further facts and information derived from our experience, if you favor us with a call at our works.

Yours truly,

D. L. Goff.

Mr. HENRY T. WHITIN. Mr. President, this is a subject that I am a great deal interested in. I fully intended to have something to say on the subject. Owing to business I was unable to do so, and I would like to ask Mr. PAINE one question. I notice in the letter just read nothing is allowed for depreciation or wear on the plant.

Mr. SIDNEY B. PAINE. I have received no further information from Mr. GOFF than that given in his letter. He allows for all the items which enter into the cost, including depreciation and interest, in the charge of 15 cents per thousand watts which he has made against the electric current. In the tables Mr. GOFF has given, he has endeavored to ascertain what the expense would be to a party who had to purchase his gas or electric current from a central station at prevailing rates in both cases."

The PRESIDENT. The next question is No. 39, "What is the best arrangement by which a manager can communicate with any department as occasion may require?"

Mr. C. J. H WOODBURY. Mr. President, I don't know who proposed this question, but it is one which has been considered by everyone engaged in the administration of a large manufacturing property. It was in Providence that the telephone was first applied to special use in mills, but that method required a switchboard and attendant. There is at the present time a new system of telephones of the American Bell Telephone Company, especially made for the service of mills. The person who wishes to speak moves an indicator or plug to the desired index, corresponding to that room, under the telephone, touches a button, and a bell rings in the telephone called, and places him in immediate communication with the person desired. All of the messages can pass through the telephone at the agent's desk. This style of telephone does not include any service to the general exchange, and the expense is correspondingly less. This telephone gives instant service at any time, is quick and reliable. There is no waiting for anything, and does not require any central switchboard and attendant.

TRANSACTIONS

OF THE

New England

Cotton Manufacturers' Association,

ORGANIZED JULY 26, 1865. INCORPORATED DEC. 1, 1894.

Office of the Association,

John Hancock Building, 178 Devonshire St., Boston, Mass.

No. 58.

ANNUAL MEETING.

(PROVIDENCE MEETING.)

HELD AT SAVOY HALL, PROVIDENCE, R. I.

APRIL 24-25, 1895.

WALTHAM, MASS.
E. L. BARRY, PRINTER.
1895.